An inventory of selected electronic, textronic, mechatronic and ICT-based solutions for safety-related applications in smart working environments

Technical report elaborated by the Central Institute for Labour Protection – National Research Institute (CIOP-PIB) on the basics of results of the project no III.P.21 as a contribution to the PEROSH project *"Concept of integration of ambient intelligence for safety and health towards smart factories"*

Authors:
Grzegorz Gralewicz (Ph.D)
Grzegorz Owczarek (Ph.D)

Central Institute for Labour Protection – National Research Institute
Warsaw, Poland
March 2015

This report is based on results of the research project no. III.P.21 (*Developing architecture of monitoring and management of occupational safety and health system including advanced technologies and solutions to create the intelligent working conditions*) carried out within the 3rd phase of the Polish National Programme "Improvement of safety and working conditions" 2014–2016, partly supported by the Ministry of Science and Higher Education and the National Centre for Research and Development. The Central Institute for Labour Protection – National Research Institute (CIOP-PIB) is the Programme's main coordinator.

An inventory methodology

The inventory of selected electronic, textronic, mechatronic and ICT-based solutions which may be potentially applied to safety-related applications in smart working environments has been elaborated on the basis of a thorough analysis of a number of documents, i.e.:

- scientific articles (127 references),
- papers published in the conference proceedings (106 positions),
- information on results of research projects (29 positions),
- information materials published by the manufacturers (40 positions).

The threshold for inclusion of a given solution into the inventory was based on a demonstrated possibility to make use of the solution to ensure the safety of workers in the intelligent working environment.

The elaborated inventory of solutions is presented in the Annex. It includes the following information:

- a name of the solution, technology/project, a photo or a diagram and a brief description underlying the operating principle of this solution (e.g. phenomena and processes, technology, algorithms, etc.),
- references to the articles, papers and/or websites,
- an indication of the **functions of the identified solution** which are important for occupational safety and health,
- an indication of a role and a position of a given solution in the risk management process and in a hierarchy of hazard protective and preventive measures.

The selected solutions were classified by assigning them some basic features which may be performed with regard to occupational health and safety, and specifically:

- monitoring of:
  - the working environment conditions (monitoring of the environmental parameters, such as chemical substances, noise, etc.),
  - workers' physiological parameters (body temperature, heart rate, user's activity, muscle performance and energy monitoring, etc.),
  - the parameters of machinery (movement detection, location, etc.),
  - protective parameters of personal protective equipment,
- warning and information support for workers (e.g. alarm signal),
- supporting decision-making processes,
- virtual reality-based training and education.

Each solution listed in the Annex was also categorised by assigning it to the certain level in the risk management process.

The following levels were considered for this purpose:

- **Machines level** – *monitoring of parameters of machines and manufacturing processes;*
- **Workers level** – *monitoring workers' health conditions, hazardous factors of working environment, PPE parameters, etc.;*
- **Management level** – *enabling managers to make decisions on the basis of an overview of current workers' health conditions, factors of working environment, PPE parameters, machines and parameters of manufacturing processes.*

The selected solutions were also analysed in terms of their assignment in the hierarchy of risk preventive and protective measures. According to the classical hierarchy (mentioned for example in ILO-OSH 2001 *Guidelines on OSH management system*) these measures should be implemented in the following order of priority:

- elimination of the hazard/risk;
- control of the hazard/risk at source, through the use of engineering controls or organisational measures;
- minimisation of the hazard/risk by the design of safe work systems, which include administrative control measures; and
- application of personal protective equipment where residual hazards /risks cannot be controlled by collective measures.

For the purpose of drawing up the inventory the following three levels were taken into account in the hierarchy of risk preventive and protective measures:

- engineering controls,
- organisational measures,
- personal protective equipment.

Annex: A list of electronic, textronic, mechatronic and ICT-based solutions for safety-related applications in smart working environments

REFERENCES

[1]. Dr. Jochen Teizer, Wearable Technologies Increase Worker Health and Safety, http://www.teizer.com

[2]. Dr. Jochen Teizer, Saving Lives & Reducing Injuries in Construction with Innovative Wearable Technologies, http://www.teizer.com/a_news_2014-02-01-HumanConditions.pdf

[3]. David Tihay, Application of RFID to occupational risk prevention at companies, http://www.saisie-mobile.eu/telechargements/inrs-application%20rfid-nd2352.pdf

[4]. Application of Mobile RFID-Based Safety Inspection Management at Construction Jobsite Yu-Cheng Lin, Yu-Chih Su, Nan-Hai Lo, Weng-Fong Cheung and Yen-Pei Chen DOI: 10.5772/53176

[5]. RFID in workplace safety solutions Jokin Rubio, Imanol Padillo, Jon Espina, Jorge Venistegui, Jesus Lopez-de-Ipifia, Fundacion LElA eDT, Vitoria-Gasteiz, Spain ITG-Fachbericht 224 - RFID Systech 2010 . 15. - 16.06.2010. Ciudad, Spain

[6]. iBeacon.com http://www.ibeacon.com/

[7]. NearFieldCommunication.org http://www.nearfieldcommunication.org/

[8]. Zhang, C., Hammad, A., and Rodriguez, S. Crane Pose Estimation using UWB Real-time Location System, Journal of Computing in Civil Engineering 26(5), p. 625–637 (2012)

[9]. Sahinoglu Z., Gezici S., Güvenc I., Ultra-wideband Positioning Systems: Theoretical Limits, Ranging Algorithms, and Protocols, Hardcover – October 6, 2008

[10]. SpecificationIEEE 802.15.1 (Bluetooth)

[11]. Specification4 (ZigBee)

[12]. ZigBee Alliance www.zigbee.org

[13]. Specification 3GPP TS 22.060 v3.5.0 GPRS. Service description; Overview

[14]. GPS.gov http://www.gps.gov/

[15]. IO-Link http://www.io-link.com/en/index.php

[16]. OLED http://www.oled-info.com/itri-6-flexible-color-amoled-photo

[17]. XOEye Technologies http://www.xoeye.com/

[18]. Travis Hessman, Wearable Computing Has Arrived on the Factory Floor http://www.industryweek.com/imts/wearable-computing-has-arrived-factory-floor-video September 15, 2014

[19]. Carolyn Heinze, Are Wearable Devices Headed for SMBs http://digital.channelprosmb.com/publication/?i=220265&p=28 September 10, 2014

[20]. Google https://www.google.com/glass/start/

[21]. Vuzix http://www.vuzix.com/consumer/products_m100/

[22]. Vuzix http://www.vuzix.com/consumer/products_m2000ar/

[23]. VRLOGIC GmbH http://www.vrlogic.com/index.php/en/datagloves

[24]. Eleksen Ltd., www.eleksen.com

[25]. Mike Hanlon, Verb for Shoe - very intelligent shoes! December 14, 2004 http://www.gizmag.com/go/3565/

[26]. BodyMedia, Inc. http://sensewear.bodymedia.com/SW-Learn-More/Product-Overview

[27]. omerh.com http://www.omerh.com/c-thru#1

[28]. Jason B. Forsyth, Thomas L. Martin, Deborah Young-Corbett, Ed Dorsa, Feasibility of Intelligent Monitoring of Construction Workers for Carbon Monoxide Poisoning, IEEE Trans. on

Automation Science and Engineering, Vol 9, No 3, July 2012 http://www.academia.edu/1790014/Feasibility_of_Intelligent_Monitoring_of_Construction_Workers_for_Carbon_Monoxide_Poisoning

[29]. Lynn Nystrom, Equipping a construction helmet with a sensor can detect the onset of carbon monoxide poisoning, Blacksburg, VA , August 16, 2013 Virginia Tech College of Engineering, http://www.eng.vt.edu/news/equipping-construction-helmet-sensor-can-reduce-fatalities

[30]. Irizarry J., Gheisari M., N. Walker B., "Usability assessment of drone technology as safety inspection tools", ITcon Vol. 17, pg. 194-212 http://www.itcon.org/cgi-bin/works/Show?2012_12

[31]. SixAxis LLC, Drones Improve Workplace Safety, http://www.erectastep.com/drones-improve-workplace-safety/

[32]. DAVE COLLINS Drones to make every workplace safe! http://www.safetyrisk.net/drones-to-make-every-workplace-safe/ 23.09.2012.

[33]. JOHNSON CONTROLS, New technologies can enhance safety and improve efficiency for facilities managers, http://www.johnsoncontrols.com/content/us/en/products/globalworkplacesolutions/workplacenow_e-zine/UAVTech.html

[34]. RoboMate http://www.robo-mate.eu/

[35]. Hans Wernher van de Venn, Robo-Mate vereint Mensch und Maschine SWISS Engineering, July/August 2013 http://www.robo-mate.eu/sites/robo-mate.eu/files/robomate_swiss_engineering_final.pdf

[36]. BBC Robo-mate exoskeleton under development in Europe 11 September 2013 http://www.bbc.com/news/technology-24048567

[37]. Smartex s.r.l. http://www.smartex.it/index.php/en/research/projects/european-projects/wealthy

[38]. R. Paradiso, T. Faetti and S. Werner, "Wearable Monitoring Systems for Psychological and Physiological State Assessment in a Naturalistic Environment", *33rd Annual International Conference of the IEEE EMBS,* Boston, Massachusetts USA, August 30 - September 3, 2011, 2250-2253

[39]. Paradiso R. and Pacelli M., "Textile electrodes and integrated smart textile for reliable Biomonitoring", *33rd Annual International Conference of the IEEE EMBS,* Boston, Massachusetts USA, August 30 - September 3, 2011, 3274-3277

[40]. Gallego J.A., Paradiso R. et al, "A soft Wearable Robot for Tremor Assessment and Suppression", *2011 IEEE International Conference on Robotics and Automations,* Shangai International Conference Center, May 9-13, 2011, Shangai, China

[41]. Paradiso R., Bianchi A.M., Lau K. and Scilingo E.P., "Phyche: Personalised Monitoring Systems for Care in Mental Health", *32nd Annual International Conference of the IEEE EMBS,* Buenos Aires, Argentina, August 31-Sepember 4, 2010, 3602-3605

[42]. Paradiso R. and Caldani L., "Electronic Textile Platforms for Monitoring in a Natural Environment", *Research Journal of Textile and Apparel*, 04-2010

[43]. Paradiso R, Taccini N., Loriga G., "Chapter 36: Textile Sensing and e-Textiles (Smart Textiles)", *The Engineering Handbook of Smart Technology for Aging, Disability and Independence*, Edited by A. Helal, M. Mokhtari and B. Abdulrazak, Copyright © 2008 John Wiley & Sons, Inc., 673-692, Published Online: 29 JAN 2008

[44]. Paradiso R, Bourdon L, Loriga G, “Smart Sensing Uniforms for Emergency Operators”, *Advances in Science and Technology,* Vol. 60 (2008) pp 101-110

[45]. Paradiso R and De Rossi D, “Advances in Textile Sensing and Actuation for E-Textile Applications”, *Proceedings of the 30th Annual Conference of the IEEE Engineering in Medicine and Biology Society*, August 20-24, 2008 Vancouver, BC Canada, pp. 3629-3629.

[46]. Taccini N, Loriga G, Pacelli M and Paradiso R, “Wearable monitoring System for Chronic cardio-Respiratory Diseases”, *Proceedings of the30th Annual Conference of the IEEE Engineering in Medicine and Biology Society*, August 20-24, 2008 Vancouver, BC Canada, pp. 3690-3693

[47]. Paradiso R, Alonso A, Cianflone D, Milsis A, Vavouras T, Malliopoulos C, “Remote monitoring with Wearable Non Invasive Mobile System: The Healthwear Project”, *Proceedings of the 30th Annual Conference of the IEEE Engineering in Medicine and Biology Society*, August 20-24, 2008 Vancouver, BC Canada, pp. 1699-1702

[48]. Loriga G., Taccini N., Pacelli M. and Paradiso R., “Flat Knitted Sensors for Respiration Monitoring”, *From Mind to Market*, FALL 2007 IEEE INDUSTRIAL ELECTRONICS MAGAZINE

[49]. Paradiso R, “Protection e-Textiles: MicroNanoStructured fibre systems for Emergency-Disaster Wear PROETEX’’, NanoItalTex 2006, 15-16 Novembre 2006

[50]. Paradiso R, “E-textiles – Sensing Textile Materials”, *Nanotechnologies and Smart Textiles for Industry and Fashion,* 11th-12th October 2006 – The Royal Society, Carlton House Terrace, London

[51]. M.Pacelli, G.Loriga, N.Taccini, R.Paradiso “Sensing Fabrics for Monitoring Physiological and Biomechanical Variables: E-textile solutions” in*Proceedings of the 3rd IEEE-EMBS International Summer School and Symposium on Medical Devices and Biosensors* , MIT, Boston, USA, Sept. 4-6, 2006

[52]. R. Paradiso, D. De Rossi “Advances in textile technologies for unobtrusive monitoring of vital parameters and movements” *Proceedings of the 28th IEEE, EMBS Annual International Conference*, New York City, USA, Aug 30-Sept 3, 2006

[53]. M.Pacelli, L. Caldani, R. Paradiso “Textile Piezoresistive Sensors for Biomechanical Variables Monitoring” *Proceedings of the 28th IEEE, EMBS Annual International Conference*, New York City, USA, Aug 30-Sept 3, 2006

[54]. M. Milanesi, N. Martini, N. Vanello, V. Positano, M. F. Santarelli, R. Paradiso, D. De Rossi, L. Landini “Multichannel Techniques for Motion Artifacts Removal from Electrocardiographic Signals” *Proceedings of the 28th IEEE, EMBS Annual International Conference*, New York City, USA, Aug 30-Sept 3, 2006

[55]. L. Bourdon, S. Coli, G. Loriga, N. Taccini, B. Gros, A. Gemignani, D. Cianflone, F. Chapotot, A. Dittmar, R. Paradiso “First Results with the Wealthy Garment ElectroCardiogram Monitoring System” *32nd annual international conference on Computers in Cardiology (CINC)*, Lyon, 25-28 September 2005

[56]. G. Loriga , N. Taccini, D. De Rossi and R. Paradiso “Textile Sensing Interfaces for Cardiopulmonary Signs Monitoring” *Proceedings of the 2005 IEEE Engineering in Medicine and Biology. 27th Annual Conference,* Shanghai, China, September 1-4, 2005. Pages:7349 – 7352.

[57]. N. Taccini, G. Loriga, A. Dittmar, R. Paradiso “Knitted Bioclothes for Health Monitoring” *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (IEEE-EMBC)*, San Francisco, CA, USA, pages 2165-2169, September 1-5, 2004

[58]. R. Paradiso, G. Loriga, N. Taccini, A. Gemignani, B. Ghelarducci "WEALTHY – a wearable healthcare system: new frontier on e-textile" in *Journal of Telecommunications and Information Technology,* vol.4, Poland, 2005

[59]. E. P. Scilingo, A. Gemignani, R. Paradiso, N. Taccini, B. Ghelarducci, D. De Rossi "Performance Evaluation of Sensing Fabrics for Monitoring Physiological and Biomechanical Variables" in *IEEE Transactions on Information Technology in Biomedicine,* vol. 9, no. 3, pages 345-352, September 2005

[60]. R. Paradiso, G. Loriga, N. Taccini "A Wearable Health Care System Based on Knitted Integrated Sensors" in *IEEE Transactions on Information Technology in Biomedicine,* vol. 9, no. 3, pages 337-344, September 2005

[61]. D. De Rossi, F. Carpi, F. Lorussi, R. Paradiso, E. P. Scilingo, A. Tognetti (2005) "Electroactive fabrics and wearable man-machine interfaces" in*Wearable electronics and photonics*, Woodhead Publishing Limited, UK

[62]. R. Paradiso, C. Belloc, G. Loriga, N. Taccini "Wearable Healthcare Systems, New Frontiers of e-Textile" International Workshop pHealth: The Integration of Innovative Sensing, Textile, Information & Communication Technologies, Belfast, Nothern Irland, December 13-15, 200

[63]. A.Bonfiglio, D. De Rossi, T. Kirstein, I. Locher, F. Mameli, R. Paradiso, G. Vozzi (2004) "A Feasibility Study of Yarns and Fibers with Annexed Electronic Functions: The ARIANNE Project" in *Wearable eHealth Systems for Personalised Health Management*, pages 324–329, A. Lymberis and D. de Rossi, Eds. Amsterdam, The Netherlands: IOS Press

[64]. MyHeart Project http://www.hitech-projects.com/euprojects/myheart/

[65]. Neue Schritte in der Telemedizin, by Harris, M.; Zugck, C. in Deutsche Aerztezeitung, August 2009

[66]. Detection of Atrial Fibrillation using model-based ECG, ICPR 2008 Conference of the International Association for Pattern Recognition (IAPR), Dec. 2008

[67]. Manifold Learning for Premature Ventricular Contraction Detection, by B. Ribeiro, J. Henriques, A. Marques, M. Antunes, in 35th Conference Computers in Cardiology, Sept. 2008

[68]. Phase Space Reconstruction Approach for Ventricular Arrhythmias Characterization, in 30th Annual International IEEE EMBS Conference at August 2008

[69]. Heart Murmur Recognition and Segmentation by Complexity Signatures, in 30th Annual International IEEE EMBS Conference at August 2008

[70]. On the Detection of Premature Ventricular Contractions, in 30th Annual International IEEE EMBS Conference at August 2008.

[71]. Sleep and quality of life in heart failure and stroke by Skobel E et al in in Sleep and quality of life in clinical illness 355-366, February 2008

[72]. High impact of depression in congestive heart failure: Early diagnosis and therapy options, byNorra C., Skobel E., Arndt M., Schauerte P. in Int J Cardiol:125: 220-231, 26 July 2007

[73]. General Project Leaflet Sensing Fabrics for Monitoring Physiological and Biomechanical Variables: E-textile solutions Published by M.Pacelli, G.Loriga., N.Taccini and R.Paradiso in Proceedings of the 3rd IEEE-EMBS International Summer School and Symposium on Medical Devices and Biosensors MIT, Boston, USA, Sept.4-6, 2006

[74]. Advances in textile technologies for unobtrusive monitoring of vital parameters and movements. Published by Rita Paradiso, Danilo De Rossi in Proceedings of the 28th IEEE EMBS Annual International Conference New York City, USA, Aug 30-Sept 3, 2006.

[75]. Long term monitoring of circadian variations of activity and ECG: Clinical application of a new data aquisition system. Published in Somnologie, Issue 3, August 2006, by Naujokat E., Arndt M., Novak D. and Norra Conference (Serious Games Summit, San Jos, USA) 2006-03
[76]. Erick A Perez Alday, Michael A Colman, Philip Langley, Timothy D Butters, Jonathan Higham, Antony J Workman, Jules C Hancox, Henggui Zhang. A New Algorithm to Diagnose Atrial Ectopic Origin from Multi Lead ECG Systems - Insights from 3D Virtual Human Atria and Torso. PLoS Computational Biology. 01/2015; 11(1):e1004026. DOI: 10.1371/journal.pcbi.1004026
[77]. Sensing Muscle Activities with Body-Worn Sensors, Published by Oliver Amft, Holger Junker, Paul Lukowicz, Gerhard Troster and Corina Schuster
[78]. ConText Project http://www.hitech-projects.com/euprojects/context/
[79]. G.R. Langereis, L. de Voogd-Claessen, A. Sipli, H. Illing Gnther, A. Spaepen, T. Linz, ConText Contactless sensors for body monitoring incorporated in textiles, FiberMed06; Conf. on Fibrous Products in Medical & Health Care, Tampere, Finland, June 7-9, 2006
[80]. Lena Gourmelon and Geert Langereis, Contactless sensors for surface electromyography, IEEE-EMBC 06, 28th Annual International Conference IEEE Engineering in Medicine and Biology Society (EMBS), New York, August 30 September 3, 2006
[81]. Lenneke de Voogd-Claessen, Auli Sipil, Heike Illing-Gnther, Geert Langereis, Torsten Linz, Arthur Spaepen,Contactless Sensors Integrated into Textiles, Nanotechnologies and Smart Textiles for Industry and Fashion, 11-12 October 2006, The Royal Society, London, UK
[82]. Contactless EMG sensors for monitoring musculoskeletal disorders, J. Taelman, S. Van Huffel, T. Adriaensen, A. Spaepen, G.R. Langereis, L. Gourmelon, IEEE-EMBS, IEEE Benelux chapter on engineering in medicine and biology, 7-8 December, 2006, Brussels, Belgium
[83]. Torsten Linz, Lena Gourmelon, Geert Langereis, Contactless EMG sensors embroidered onto textile, BSN2007 - Body Sensor Networks, 4th International Workshop on Wearable and Implantable Body Sensor Networks, Aachen, Germany, 26-28 March, 2007
[84]. G.R. Langereis, L. de Voogd-Claessen, A. Sipli, C. Rotsch, A. Spaepen, T. Linz, ConText Contactless sensors for body monitoring incorporated in textiles, Portable 07, IEEE Conference on Portable Information Devices, Orlando, Florida, March 25-29, 2007
[85]. Torsten Linz, Embroidered Interconnections and Encapsulation for Electronics in Textiles for Wearable Electronics Applications, Advances in Science and Technology Vol. 60 (2008) pp 85 94, Trans Tech Publications, Switzerland
[86]. Taelman e.a., Influence of mental stress on Heart rate and heart rate variability, Proceedings of the eMBEC 2008 conference.
[87]. Ofseth http://www.ofseth.org/
[88]. F. Pirotte, “Optical fibre sensors embedded into technical textile for healthcare”, Proceedings of Textile Trends 2007, Berlin, 2007.
[89]. A. Grillet, “Using smart textiles to monitor health: the OFSETH project”, Proceedings of the 4th Symposium on Technical Textiles Market, Porto, 2007
[90]. A. Grillet, “Optical fibre sensors embedded into technical textile for healthcare”, Tutorial on SFIT, 4th International Workshop on Wearable and Implantable Body Sensor Networks (BSN’07), Aachen, 2007
[91]. F. Pirotte and A. Grillet, “Optical fibre sensors embedded into technical textile for healthcare”, Proceedings of 4th International Avantex-Symposium for Innovative Apparel Textiles, Frankfurt, 2007

[92]. A. Grillet, D. Kinet, J. Witt, M. Schukar, K. Krebber, F. Pirotte and A. Depré, ”Optical fibre sensors embedded into medical textiles for monitoring of respiratory movements in MRI environment”, Proceedings of 4th European Workshop on Optical Fibre Sensors (EWOFS’07), Napoly, 2007

[93]. F.Pirotte , A. Depre , R.Shishoo, J. De jonckheere and A. Grillet, “Smart textiles embedded with optical fibres sensors for health monitoring of patients”, Proceedings of 4th International Conference and Exhibition on Healthcare and Medical Textiles (MedTex07), Bolton, 2007

[94]. J. De jonckheere, M. Jeanne, A. Grillet, S. Weber, P. Chaud, R. Logier and JL. Weber, OFSETH: Optical Fibre Embedded into technical Textile for Healthcare, an efficient way to monitor patient under magnetic resonance imaging, Proceedings of the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC’07), Lyon, 2007

[95]. D.Kinet, J.Wittz, A.Grillet, M.Schukar, D. Giannone and F.Pirotte, “Silica f fibre Bragg Grafting Sensor embedded into a textile Fabric for large strain applications”, Proceedings of Bragg Gratings, Photosensitivity and Poling in Glass Waveguides (BGPP’07), Quebec, 2007.

[96]. K. Krebber, A. Grillet, J. Witt, M. Schukar, D. Kinet, T. Thiel, F. Pirotte and A. Depré, “Optical Fibre Sensors Embedded intoTechnical Textiles for Healthcare (OFSETH)", Proceedings of the 16th International Conference on Plastic Optical Fibres (POF 2007), Torino, 2007

[97]. PROETEX www.proetex.org

[98]. M. Maccioni, E. Orgiu, P. Cosseddu, S. Locci, A. Bonfiglio, “Towards the textile transistor: assembly and characterization of an Organic Field Effect Transistor with a cylindrical geometry”, Applied Physics Letters, 89, 143515:1-3, 2006 (selected for publication on the Virtual Journal of Nanoscale Science and Technology of the American Institute of Physics and the American Physical Society).

[99]. Manunza, A. Sulis, A. Bonfiglio “Pressure sensing by flexible, organic, field effect transistors”, Applied Physics Letters, *89*, 143502:1-3, 2006 (selected for publication on the Virtual Journal of Nanoscale Science and Technology of the American Institute of Physics and the American Physical Society)

[100]. B. Fraboni, A. Matteucci, A. Cavallini, E. Orgiu, A. Bonfiglio, "Photocurrent studies of stress and ageing in Pentacene Thin Film Transistors", Applied Physics Letters, *89*, 222112:1-3, 2006

[101]. Manunza, A. Sulis, A. Bonfiglio, “Organic semiconductor field effect transistors for unconventional applications: flexible sensors and wearable devices”, Body Sensor Network Workshop, MediaLab, Boston 3-5 April, 2006

[102]. Manunza, E. Orgiu, A. Caboni, M. Barbaro, A. Bonfiglio, “Producing smart sensing films by means of organic field effect transistors”, IEEE-EMBS, New York, 30 August – 3 September 2006

[103]. M. Maccioni, E. Orgiu, P. Cosseddu, S. Locci, A. Bonfiglio, “The textile transistor: a perspective for distributed, wearable networks of sensor devices” ISSS-MDBS (3rd International Summer School and Workshop on Medical Devices and Biosensors), Boston 4-7 September 2006

[104]. A.Tronquo, H. Rogier, C. Hertleer and L. Van Langenhove, “A Robust Planar Textile Antenna for Wireless Body LANs Operating in the 2.45-GHz ISM band.,” IEE Electronics Letters, vol. 42, no. 3, pp. 142–143, Feb. 2006

[105]. A.Hertleer, F. De Clercq, A. Tronquo, H. Rogier and L. Van Langenhove, “Design of Texile Antennas for Smart Clothing,” 2006 AUTEX Conference (Proceedings available on CD-ROM), Rayleigh, USA, pp. 1–7, Jun. 2006

[106]. A.Tronquo, H. Rogier, C. Hertleer and L. Van Langenhove, “Applying textile materials for the design of antennas for wireless body area networks.”, Proceedings of the European Conference on Antennas & Propagation – EUCAP 2006 (Proceedings available on CD-ROM, paper #305567), Nice, France, p. 159, Nov. 2006
[107]. A.Hertleer, H. Rogier and L. Van Langenhove, “Antennas for wireless body area networks, made out of textile materials,” International Conference “Futurotextiles”, pp. 8–14, Lille, France, Nov. 2006
[108]. Van Langenhove L., ; Hertleer, C ; Nieuws uit de vakgroep textielkunde: Pro-e-TEX, e-textiles voor beschermkleding bij rampen ; UNITEX newsletter 1: 44-44 MAART 2006
[109]. Pacelli M, Loriga G, Paradiso R "Flat Knitted Sensors for Respiration Monitoring", Industrial Electronics, 2007. ISIE 2007. IEEE International Symposium on 4-7 June 2007
[110]. A. Hertleer, H. Rogier, L. Van Langenhove, "A TEXTILE ANTENNA FOR PROTECTIVE CLOTHING", http://www.proetex.org/Publications/2007-04-24%20A&P%20for%20BCWC%20paper%20Carla%20Hertleer.pdf
[111]. A.Hertleer, H. Rogier. and L. Van Langenhove, "A Textile Antenna for Protective Clothing", http://www.proetex.org/Publications/2007-06%20pHealth%20Carla%20Hertleer.pdf
[112]. C. Hertleer, L. Van Langenhove, H. Rogier, L. Vallozzi, "A TEXTILE ANTENNA FOR FIRE FIGHTER GARMENTS", http://www.proetex.org/Publications/2007%20AUTEX%20Paper%20Carla%20Hertleer.pdf
[113]. CIOP-PIB http://www.i-protect.pl/
[114]. talk2myShirt, Intelligent clothing for the safety of Firefighters http://www.talk2myshirt.com/blog/archives/390 23.09.2012.
[115]. ClimaTech http://www.climatechsafety.com/
[116]. Natick, Adaptable ‘skin’. Hydrogel changes wet suit’s water flow for better protection, http://www.natick.army.mil/about/pao/pubs/warrior/02/mayjune/smartskin.htm
[117]. Vivonoetics, LifeShirt, http://vivonoetics.com/products/sensors/lifeshirt/
[118]. Kyle AM, Rogers PI, Han S, Chen PS, March KL., LifeShirt acquisition system to monitor ECG from ambulatory swine and the implementation of an arrhythmia detection algorithm, IEEE Eng Med Biol Soc. 2009;2009:4820-3. doi: 10.1109/IEMBS.2009.5332632.
[119]. López G.,CustodioV., Moreno J.I., LOBIN: E-Textile and Wireless-Sensor-Network-Based Platform for Healthcare Monitoring in Future Hospital Environments, IEEE Trans. on Information Technol. In Biomedicine, 14(6), (2010), 1446-1458
[120]. DunneL.E.,Brady S., Diamond D.,Initial development and testing of a novel foam-based pressure sensor for wearable sensing, J NeuroengineeringRehabil.; 2 (2005)
[121]. Varadan V. K., KumarP. S., OhS., KwonH., RaiP., BanerjeeN., HarbaughR. E., e-Nanoflex Sensor System: Smartphone-Based Roaming Health Monitor, J. Nanotechnol. Eng. Med.–2 (2011) no. 1
[122]. Byfordon S., Adidas miCoach Elite System to be integrated in Major League Soccer from 2013, 20.06.2012.http://www.theverge.com/2012/7/20/3171410/adidas-micoachelite- system-major-league-soccer
[123]. Textronics, Inc. www.NuMetrex.com
[124]. FitzgeraldM., Use a Heart Rate Monitor to Measure Heart Rate Recovery - An Important Measure of Fitness, 01.07.2009.http://www.numetrex.com/op/use-a-heart-rate-monitor-tomeasure- heart-rate-recovery-an-important-measure-of-fitness
[125]. Grado Zero Espace srl http://www.gradozero.eu/

[126]. warmX GmbH http://www.wellness.warmx.de/
[127]. MICROFLEX http://microflex.ecs.soton.ac.uk/
[128]. Y Wei, R Torah, K Yang, S Beeby, J Tudor., A novel fabrication process to realise piezoelectric cantilever structures for smart fabric sensor applications, IEEE Sensors, Oct 2012, Taipei, Taiwan
[129]. Dephotex http://www.dephotex.com/
[130]. DU BRULLE,CHRISTIAN, Le textile se fait photovoltaïque... Mercredi 8.09.2010
[131]. Dan Rogers, Electronic sportswear on track for 2010, 09 Oct 2009
[132]. PLACE-it http://www.place-it-project.eu/
[133]. Torsten Linz, Malte von Krshiwoblozki, Hans Walter & Philipp Foerster, Contacting electronics to fabric circuits with nonconductive adhesive bonding, The Journal of The Textile Institute, Volume 103, Issue 10, 2012, pages 1139-1150, DOI: 10.1080/00405000.2012.664867
[134]. Schock-Kusch D, Shulhevich Y, Xie Q, Hesser J, Stsepankou D, Neudecker S, Friedemann J, Koenig S, Heinrich R, Hoecklin F, Pill J, Gretz N, Online feedback-controlled renal constant infusion clearances in rats, Kidney Int. 2012 Aug;82(3):314-20. doi: 10.1038/ki.2012.117. Epub 2012 Apr 18
[135]. Schreiber A, Shulhevich Y, Geraci S, Hesser J, Stsepankou D, Neudecker S, Koenig S, Heinrich R, Hoecklin F, Pill J, Friedemann J, Schweda F, Gretz N,Schock-Kusch D, Transcutaneous measurement of renal function in conscious mice Am J Physiol Renal Physiol. 2012 Sep;303(5):F783-8. doi: 10.1152/ajprenal.00279.2012. Epub 2012 Jun 13
[136]. de Vries, H. ; Philips Res., Eindhoven, Netherlands ; Cherenack, K.H. ; Schuurbiers, R. ; van Os, K., Failure Modes in Textile Interconnect Lines, Electron Device Letters, IEEE (Volume:33 , Issue: 10), Oct. 2012, p. 1450 – 1452, DOI: 10.1109/LED.2012.2210186.
[137]. Kunigunde Cherenack and Liesbeth van Pieterson, Smart textiles: Challenges and opportunities, J. Appl. Phys. 112, 091301 (2012); http://dx.doi.org/10.1063/1.4742728
[138]. J. Vanflfleteren , M. Gonzalez , F. Bossuyt , Y.-Y. Hsu , T. Vervust, I. De Wolf , And M. Jablonsk, Printed Circuit Board Technology Inspired Stretchable Circuits, MRS Bulletin — VOLUME 37, NUMBER 3, 2012
[139]. Thomas Vervust, Guy Buyle, Frederick Bossuyt & Jan Vanfleteren, Integration of stretchable and washable electronic modules for smart textile applications, The Journal of The Textile Institute, Volume 103, Issue 10, 2012
[140]. BialD., KernD., AltF., Schmidt A., Enhancing Outdoor Navigation Systems Through Vibrotactile Feedback,CHI ’11 Extended Abstracts on Human Factors in Computing Systems`, New York, NY, USA, 2011, 1273-1278
[141]. Garland I., Ukrainian inventors create a 'super' glove for the deaf that converts sign language into speech,Mail Online Science and Tech, 11 July 2012, http://www.dailymail.co.uk/sciencetech/article-2171677/Ukrainian- inventors-create-super-glove-convertssign-language-speech.html
[142]. HÖVDING http://www.hovding.com/
[143]. Myontec http://www.myontec.com/home/
[144]. MIT program in Media Arts and Sciences http://web.media.mit.edu/~awhiton/ipv.htm
[145]. A Wearable for Physical Abuse Detection, Whiton, A. ; Nugent, Y. Wearable Computers, 2007 11th IEEE International Symposium on DOI: 10.1109/ISWC.2007.4373796 Publication Year: 2007 , Page(s): 119 – 120
[146]. schoeller http://www.schoeller-textiles.com/en/technologies/schoeller-pcm.html

[147]. Phenix http://www.phenix.net.pl/technologies.php5
[148]. W. L. Gore & Associates (UK) Ltd. http://www.gore-tex.pl/
[149]. 3M, Wskaźnik poziomu natężenia hałasu NI-100, http://catalogue.3m.eu/pl-PL/PL-PPE/Urz%C4%85dzenia_pomiarowe/Pomiar_nat%C4%99%C5%BCenia_ha%C5%82asu/td~Wska%C5%BAnik_poziomu_nat%C4%99%C5%BCenia_ha%C5%82asu~NI-100/Wska%C5%BAnik_poziomu_nat%C4%99%C5%BCenia_ha%C5%82asu~NI-100
[150]. PILZ, System kamer bezpieczeństwa SafetyEYE, https://www.pilz.com/pl-PL/eshop/00014000337042/SafetyEYE-Safe-camera-system
[151]. FASyS http://www.fasys.es/en/
[152]. Integrated and Personalised Risk Management in the Sensing Enterprise, Óscar Lázaro, Agustín Moyano, Mikel Uriarte, Alicia González, Teresa Meneu, Juan Carlos Fernández-Llatas, Vicente Traver, Benjamín Molina, Carlos Palau, Óscar López, Etxahun Sánchez, Saioa Ros, Antonio Moreno, María González, José Antonio Palazón, Miguel Sepulcre, Javier Gozálvez, Luis Collantes and Gonzalo Prieto, Risk Management - Current Issues and Challenges", book edited by Nerija Banaitiene, ISBN 978-953-51-0747-7, Published: September 12, 2012 under CC BY 3.0 license, DOI: 10.5772/50275
[153]. Virtual Factory Framework http://www.vff-project.eu/
[154]. VFF: Virtual Factory Framework, M. Sacco, P. Pedrazzoli1111, W. Terkaj, ICE Conference 2010, Lugano, CH.
[155]. Virtual Factory Manager, M. Sacco, G. Dal Maso, F. Milella, P. Pedrazzoli and D. Rovere, et al., Lecture Notes in Computer Science, 2011, Volume 6774, Virtual and Mixed Reality – Systems and Applications, Pages 397-406.
[156]. Virtual Factory Manager of Semantic Data, G. Ghielmini, P. Pedrazzoli, D. Rovere, W. Terkaj, C.R. Boer, G. Dal Maso, F. Milella, M. Sacco, DET Conference 2011, Athens, GR
[157]. Terkaj W, Pedrielli G, Sacco M (2012) Virtual Factory Data Model. Proceedings of OSEMA 2012 Workshop, 7th International Conference on Formal Ontology in Information Systems, Graz, Austria, July 24-27, 2012
[158]. Terkaj W, Urgo M (2012) Virtual Factory Data Model to support Performance Evaluation of Production Systems. Proceedings of OSEMA 2012 Workshop, 7th International Conference on Formal Ontology in Information Systems, Graz, Austria, July 24-27, 2012.
[159]. ActiPret, Interpreting and Understanding Activities of Expert Operators for Teaching and Education, http://actipret.acin.tuwien.ac.at/Sites/frameset.htm
[160]. A.J. Howell, K. Sage, H. Buxton, "Developing Task-Specific RBF Hand Gesture Recognition" Gesture-Based Communication in Human-Computer Interaction: 5th International Gesture Workshop, Genova, Italy, April 15-17, 2003 Springer-Verlag Heidelberg, 2004 p269-276.
[161]. H. Buxton,"Learning and understanding dynamic scene activity: a review" Image and Vision Computing, 21/1 p.125-136, 2003.
[162]. ROBO-PARTNER http://www.robo-partner.eu/
[163]. ROSETTA http://www.fp7rosetta.org/
[164]. S. Oberer-Treitz, “New Safety Paradigm in Human-Robot-Cooperation” Workshop presentation in: “Safe Human Robot Interaction with Industrial and Service Robots” at European Robotics Forum 2012, Odense, 06.03.2012.
[165]. P. Rocco, “Active Control of Safety: the ROSETTA Approach “ Workshop presentation in: “Safe Human Robot Interaction with Industrial and Service Robots” at European Robotics Forum 2012, Odense, 06.03.2012.

[166]. ICRA 2010 Workshop on Innovative Robot Control Architectures for Demanding (Research) Applications—How to Modify and Enhance Commercial Controllers, 2010 IEEE Int. Conf. Robotics and Automation (ICRA2010), Anchorage, Alaska, May 3, 2010.
[167]. LIAA http://www.project-leanautomation.eu/index.php
[168]. PR_01_EN: Efficient Division of Labor between Humans and Robots in Assembly Systems (2013-10-21) http://www.project-leanautomation.eu/fileadmin/Files/LIAA_Press_Release_EN_2013-10-21.v.1.00.pdf
[169]. Rybski P., Anderson-Sprecher P., Huber D., Niessl Ch., Simmons R., Sensor Fusion for Human Safety in Industrial Workcells, Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), October, 2012.
[170]. FANUC http://www.fanucfa.pl/
[171]. WordPress 3.5.1www.augmented-reality.pl/
[172]. "Handbook of Virtual Environments: Design, Implementation, and Applications", pod redakcją Kelly S. Hale,Kay M. Stanney, Taylor and Francis, 2014
[173]. "Handbook of Augmented Reality" Editor Borko Furht Department of Computer and Electrical Engineering and Computer Science Florida Atlantic University Glades Road 777 33431 Boca Raton, Florida
[174]. "Augmented Reality-based factory planning - an application tailored to industrial needs", Pentenrieder, K. ; Tech. Univ. Munich, Munich ; Bade, C. ; Doil, F. ; Meier, P., Mixed and Augmented Reality, 2007, ISMAR 2007. 6th IEEE and ACM International Symposium Industrial augmented reality US 7126558 B1 http://www.google.com/patents/US7126558
[175]. Javier Irizarry, Masoud Gheisari, Graceline Williams, Bruce N. Walker Automation in Construction, 2012 http://sonify.psych.gatech.edu/~walkerb/publications/pdfs/2013AUTOCON-GheisariIrizarryWalker.pdf.pdf
[176]. X Wang, M Truijens, L Hou, Y Wang, Y Zhou, Automation in Construction, 2014
[177]. Fraunhofer IIS, Sophisticated High-speed Object Recognition Engine, http://www.iis.fraunhofer.de/en/ff/bsy/tech/bildanalyse/shore-gesichtsdetektion.html
[178]. A visionary world premier: Fraunhofer IIS presents world's first emotion detection app on Google Glass, Aug 27, 2014.http://www.iis.fraunhofer.de/en/pr/2014/20140827_BS_Shore_Google_Glas.html
[179]. Saphari http://www.saphari.eu/
[180]. S. Haddadin, P. Robuffo Giordano, A. Peer, "Editorial special issue on autonomous physical Human-Robot Interaction", International Journal of Robotics Research, vol. 31, no. 13, pp. 1529-1530, 2012
[181]. C. Papazov, S. Haddadin, S. Parusel, K. Krieger, and D. Burschka, "Rigid 3D geometry matching for grasping of known objects in cluttered scenes", International Journal of Robotics Research, vol. 31, no. 4, pp. 538-555, 2012
[182]. A. Sisbot, and R. Alami, "A human-aware manipulation planner", IEEE Transactions on Robotics, vol. 28, no. 5, pp. 1045-1057, 2012.
[183]. A.Flacco, A. De Luca, I. Sardellitti, N. Tsagarakis, "On-line estimation of variable stiffness in flexible robot joints," International Journal of Robotics Research, vol. 31, no. 13, pp. 1556-1577, 2012

[184]. D. J. Braun, F. Petit, F. Huber, S. Haddadin, P. van der Smagt, A. Albu-Schäffer, S. Vijayakumar, "Robots driven by compliant actuators: Optimal control under actuation constraints," IEEE Transactions on Robotics, vol. 29, no. 5, 2013, 10.1109/TRO.2013.2271099.
[185]. S. Haddadin, S. Haddadin, A. Khoury, T. Rokahr, S. Parusel, R.Burgkart, A. Bicchi, A. Albu-Schäffer, "Biomechanisch sichere Geschwindigkeitsregelung für die Mensch-Roboter Interaktion," At – Automatisierungstechnik, in press
[186]. S. Haddadin, S. Haddadin, A. Khoury, T. Rokahr, S. Parusel, R. Burgkart, A. Bicchi, A. Albu-Schäffer, "On making robots understand safety: Embedding injury knowledge into control," International Journal of Robotics Research, vol. 31, no. 13, pp. 1578-1602, 2012.
[187]. A.Ajoudani, N.G. Tsagarakis, A. Bicchi, "Tele-impedance: Teleoperation with impedance regulation using a body-machine interface", International Journal of Robotics Research, vol. 31, no. 13, pp. 1643-1656, 2012
[188]. D. Gan, N.G. Tsagarakis, J. S. Dai, D. G. Caldwell, L. D. Seneviratne, "Stiffness Design for a spatial 3-DOF Serial Compliant Manipulator Based on Impact Configuration Decomposition," ASME Transaction of Mechanisms and Robotics, vol. 5, no.1, 2012, 10.1115/1.4007492.
[189]. M. Ghallab, D. Nau, P. Traverso, "The actor's view of automated planning and acting: A position paper," Artificial Intelligence, 2014, vol. 208, pp. 1-17, 2014, 10.1016/j.artint.2013.11.002
[190]. T. Kruse, A. K. Pandey, R. Alami, A. Kirsch, "Human-aware robot navigation: A survey," Robotics and Autonomous Systems, vol. 61, pp. 1726-1743, 2013, 10.1016/j.robot.2013.05.007
[191]. A.Kumar Pandey, M. Ali, R. Alami, "Towards task-aware, proactive-sociable robot based on multi-state perspective-taking," International Journal of Social Robotics, vol. 5, no. 2, pp. 215-236, 2013, 10.1007/s12369-013-0181-3
[192]. A.Sadeghian, L. Villani, M. Keshmiri, B. Siciliano, "Dynamic multi-priority control in redundant robotic systems," Robotica, vol. 37, pp. 1155-1167, 2013, 10.1017/S0263574713000416
[193]. A.Sadeghian, L. Villani, M. Keshmiri, B. Siciliano, "Task space control of robot manipulators with null space compliance," IEEE Transactions on Robotics, 2014, 10.1109/TRO.2013.2291630
[194]. A.Winkler, G. Bartels, L. Mösenlechner, M. Beetz, "Knowledge enabled high-level task abstraction and execution," Journal of Advances in Cognitive Systems, vol. 2, pp. 131-149, 2012
[195]. AUTORECON http://www.autorecon.eu/
[196]. G. Michalos, K. Kaltsoukalas, P. Aivaliotis, P. Sipsas, A. Sardelis, G. Chryssolouris, "Design and simulation of assembly systems with mobile robots", CIRP Annals-Manufacturing Technology, Available Online (2014)
[197]. S. Makris, G. Michalos, G. Chryssolouris, "Virtual Commissioning of an Assembly Cell with Cooperating Robots", Advances in Decision Sciences Volume 2012, Article ID 428060, 11 pages (2012)
[198]. A.Azpiazu, G. Azkune, S. Makris, A. Eytan, O. Tokcalar, "Autonomous, Exchangeable and Mobile Production Units in Industrial Assembly Production Lines", (ICRA) IEEE International Conference on Robotics and Automation , (IMAR2013) 1st Workshop on Industrial Mobile Assistance Robots, 6-10 May, Karlsruhe (2013)
[199]. P. Tsarouchi, G. Michalos, S. Makris, G. Chryssolouris, "Vision System for Robotic Handling of Randomly Placed Objects", Procedia CIRP, (CIRPe2013) 2nd CIRP Global Web Conference, Volume 9, pp. 61-66 (2013)

[200]. G. Michalos, S. Makris, A. Eytan, S. Matthaiakis, G.Chryssolouris, "Robot Path Correction Using Stereo Vision System ", (CIRP-CMS2012) 45th CIRP Conference on Manufacturing Systems, Athens, Greece, Procedia CIRP Volume 3, pp.352-357 (2012)
[201]. S. Lu, D. Zlatanov, X. Ding, R. Molfino, A Novel Prism Deployable Mechanism Based on Straight-line Mechanism, Proceedings of the MEDER 2012, 2nd IFToMM Symposium on Mechanism Design for Robotics, October 12-14 2012
[202]. Z. Ahmad, M. Zoppi, R. Molfino, Preliminary Study on Fixture Layout Optimization Using Element Strain Energy, ICMSE 2013: International Conference on Manufacturing Systems Engineering, April 14-15
[203]. S. Lu, D. Zlatanov, X. Ding, R. Molfino, M. Zoppi, A Novel Deployable Mechanism with Two Decoupled Degrees of Freedom, Proceedings of the ASME 2013 International Design Engineering Technical Conferences &Computers and Information in Engineering Conference, IDETC/CIE, August 4- 7, 2013
[204]. x-act http://www.xact-project.eu/
[205]. Copernico http://www.copernico.co/
[206]. Baldwin J, Rose-Andersson C and Ridgway K, 2011, Linnaean and Cladistic Classifications of Manufacturing Systems, 4th International Conference on Changeable, Agile, Reconfigurable and Virtual Production, 2-5 October Montreal, published in Enabling Manufacturing Competitiveness and Economic Sustainability, pp. 29-33
[207]. Rose-Andersson C, Baldwin J and Ridgway K, 2011, Cladistic Classification of Ancient Manufacturing Forms and Technologies, 4th International Conference on Changeable, Agile, Reconfigurable and Virtual Production, 2-5 October Montreal, published in Enabling Manufacturing Competitiveness and Economic Sustainability, pp. 551-556
[208]. Haraszkó C, Németh I,2012, Automatic Creation of Simulation Models of Manufacturing System Layout Variants Classified by Cladistic Method, 8th International Conference on Mechanical Engineering, 24-25 May 2012, Budapest, Hungary
[209]. Haraszkó C, Németh I,2012, Automatic Creation of Simulation Models of Manufacturing System Layout Variants (in Hungarian) Bitay (ed.), Fiatal Műszakiak Tudományos Ülésszaka XVII. Kolozsvár, Romania, (ErdélyiMúzeum-Egyesület), pp. 155-158
[210]. Baldwin J, Rose-Andersson C and Ridgway K, 2012, Evolving Manufacturing Systems: Hierarc
[211].
[212]. hical and Cladistic Classifications, EURAM 6-8 June, Rotterdam
[213]. Rose-Andersson C, Baldwin J and Ridgway K, 2012, The Evolution of Manufacturing Man and his Manufacturing Species, EURAM 6-8 June, Rotterdam
[214]. Rose-Andersson C, Baldwin J, Ridgway K, Bottinger F, Kodua K, Brencsics I & Nemeth I, 2012, Methodologies for Practical Applications of Unified Linnaean and Cladistic Classifications of Production Systems, ICOSCM, 14-18 July, Xi'an, China
[215]. Reddish S, Freeman C, 2012, Discrete Event Simulation using Immersive Virtual Reality for Factory Simulation, Joint Virtual Reality Conference, 17-19 October, Madrid
[216]. Rose-Andersson C, Baldwin J, and Ridgway K, 2012, Hierarchical and cladistic classification for the improvement of manufacturing systems, 15th Annual Conference of the Irish Academy of Management, 5-7 September, Dublin
[217]. Nemeth I, Puspoki J, Rose-Andersson C, Baldwin J, Haraszko C & Ridgway K, 2012, Cladistic Classification and Rapid Layout Design of Manufacturing Systems, International Conference on Manufacturing Research, 11-13 September, Aston UK

[218]. Rose-Andersson C, Baldwin J, Ridgway K, Boettinger F,Agyapong-Kodua K, Brencsics I, Nemeth I, 2012, Application of Production System Classification in Rapid design and Virtual Prototyping, 14th International Conference on Modern Information Technology in the Innovation Processes of the Industrial Enterprise, 24-26 October, Budapest, Hungary
[219]. Aggogeri F, Borboni A, Faglia R, Mazzola M, 2013, A novel logic and approach to speed up simulation and analysis of production systems, Journal of Convergence Information Technology vol 8 (3), pp.702-710
[220]. Nemeth, I, Puposki J, Matyasi G, Nagy T, Freeman C, Scott R & Baldwin J, 2013, 3D Design Support for Rapid Virtual Prototyping of Manufacturing Systems, 46th CIRP Conference on Manufacturing Systems vol 7, pp. 431–436
[221]. Baldwin, J, 2013, Hierarchical and Cladistic Classifications of Manufacturing Systems: A Basis for Applying Generalised Darwinism?, EURAM 13, 26-29 June 2013, Istanbul, Turkey
[222]. Aggogeri F, Maneia G, Mazzola M, Merlo A, Pellegrini N, Venturi, N, 2013, An integrated approach in modeling and simulating production and transactional systems, 26th European Conference on Operational Research (EURO 2013), 1-4 July 2014, Rome, Italy
[223]. Haraszko, CS, Nemeth, I & Baldwin, JS, 2013, DES configurators for Rapid Prototyping of Manufacturing Systems, International Conference on Innovative Technologies - IN-TECH 2013, 10-12 Sept 2013, Budapest, Hungary
[224]. WAGO http://www.wago.pl/
[225]. Scada Program http://www.scadasoftware.net/
[226]. Business Intelligence Portal http://bi.pl/keyword/1-business-intelligence
[227]. Amazon Elastic Compute Cloud (Amazon EC2) http://www.amazon.com/ec2
[228]. Cloud computing model based on MPI and OpenMP Ying Peng; Fang Wang Computer Engineering and Technology (ICCET), 2010 2nd International Conference on Volume: 7 DOI: 10.1109/ICCET.2010.5485354 Publication Year: 2010 , Page(s): V7-85- V7-87.
[229]. A I R Lab, Ambient Intelligence Research Lab, http://airlab.stanford.edu/index.html
[230]. Chin-Teng Lin ; Lee, C.S.G. “Reinforcement structure/parameter learning for neural-network-based fuzzy logic control systems” Fuzzy Systems, IEEE Transactions on Volume: 2 , Issue: 1 DOI: 10.1109/91.273126 Publication Year: 1994 , Page(s): 46 – 63.
[231]. Kumile, C.M. ; Tlale, N.S. “Intelligent distributed fuzzy logic control system (IDFLCS) of a mecanum wheeled autonomous guided vehicle” Mechatronics and Automation, 2005 IEEE International Conference Volume: 1 DOI: 10.1109/ICMA.2005.1626535 Publication Year: 2005 , Page(s): 131 - 137 Vol. 1
[232]. Phokharatkul, P. ; Phaiboon, S. “Mobile robot control using type-2 fuzzy logic system” Robotics, Automation and Mechatronics, 2004 IEEE Conference on Volume: 1 DOI: 10.1109/RAMECH.2004.1438934 Publication Year: 2004 , Page(s): 296 - 299 vol.1
[233]. Wang Ting ; Wang Heng ; Xie Hao-fei, “Research on networked synchronization control model by the combination of genetic algorithm and support vectormachine”, Computer and Automation Engineering (ICCAE), 2010 The 2nd International Conference on Volume: 3 DOI: 10.1109/ICCAE.2010.5452040 Publication Year: 2010 , Page(s): 231 – 234
[234]. Gilja, V. ; Nuyujukian, P. ; Chestek, C.A. ; Cunningham, J.P. ; Yu, B.M. ; Fan, J.M. ; Ryu, S.I. ; Shenoy, K.V. “A brain machine interface control algorithm designed from a feedback control perspective”, Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE DOI: 10.1109/EMBC.2012.6346180 Publication Year: 2012 , Page(s): 1318 – 1322

[235]. Shuying Xie ; Chengjin Zhang ; Xiangli Xiao “Adaptive Inverse Induction Machine Control Based on Variable Learning Rate BP Algorithm” Automation and Logistics, 2007 IEEE International Conference on DOI: 10.1109/ICAL.2007.4338973
Publication Year: 2007 , Page(s): 2367 – 2372
[236]. Zhiqiang Gao ; Trautzsch, T.A. ; Dawson, J.G. “A stable self-tuning fuzzy logic control system for industrial temperature regulation” Industry Applications Conference, 2000. Conference Record of the 2000 IEEE Volume: 2
DOI: 10.1109/IAS.2000.881990 Publication Year: 2000 , Page(s): 1232 - 1240 vol.2
[237]. Yaobin Chen ; Mingheng Wang ; Lyashevskiy, S. “DSP-based fuzzy logic control of a positioning system-experimental results” American Control Conference, 1997. Proceedings of the 1997 Volume: 2 DOI: 10.1109/ACC.1997.609735 Publication Year: 1997 , Page(s): 1256 - 1257 vol.2
[238]. Sugiyono, A. “Cellular Manufacturing System Aplication On Redesign Production Layout With Using Heuristics Algorithm” Management of Innovation and Technology, 2006 IEEE International Conference on Volume: 2 DOI: 10.1109/ICMIT.2006.262360 Publication Year: 2006 , Page(s): 940 – 944
[239]. Li Juntao ; Liu Bingwu “Study of Logistics Distribution Network Planning Based on Heuristic Algorithm ”Intelligent Computation Technology and Automation (ICICTA), 2011 International Conference on Volume: 1 DOI: 10.1109/ICICTA.2011.284 Publication Year: 2011 , Page(s): 1129 – 1133.
[240]. Zhang R Q, Li J Q, Li D J and Xu J J 2011 Study of the structural design and capacitance characteristics of fabric sensor Adv. Mater. Res. 194–196 1489–95
[241]. Avloni J, Lau R, Ouyang M, Florio L, Henn A R and Sparavigna A 2008 Polypyrrolecoated nonwovens for electromagnetic shielding J. Ind. Text. 38 55–68
[242]. Holleczek T, R¨uegg A, Harms H and Tr¨oster G 2010 Textile pressure sensors for sports applications 9th IEEE Sensors Conf. (Kona, HI).
[243]. Sergio M, Manaresi N, Campi F, Canegallo R, Tartagni M and Guerrieri R 2003 A dynamically reconfigurable monolithic CMOS pressure sensor for smart fabric IEEE J. SolidState Circuits 38 966–75
[244]. Hasegawa Y, Shikida M, Ogura D and Sato K 2007 Novel type of fabric tactile sensor made from artificial hollow fiber Proc. 20th Int. Conf. on Micro Electro Mechanical Systems (Hyogo, Japan).
[245]. Cho G, Jeong K, Paik M J, Kwun Y and Sung M 2011 Performance evaluation of textilebased electrodes and motion sensors for smart clothing IEEE Sensors J. 11 3183–93
[246]. Hoffmann T, Eilebrecht B and Leonhardt S 2011 Respiratory monitoring system on the basis of capacitive textile force sensors IEEE Sensors J. 11 1112–9
[247]. Meyer J, Arnrich B, Schumm J and Troster G 2010 Design and modeling of a textile pressure sensor for sitting posture classification IEEE Sensors J. 10 1391–8
[248]. Post E R, Orth M, Russo P R and Gershenfeld N 2000 Ebroidery: design and fabrication of textilebased computing IBM Syst. J. 39 840–60
[249]. Takamatsu S, Kobayashi T, Shibayama N, Miyake K and Itoh T 2011 Meterscale surface capacitive type of touch sensors fabricated by weaving conductivepolymercoated fibres Symp. on Design, Test, Integration and Packaging of MEMS/MOEMS DTIP (Bernin, France).
[250]. Hasegawa Y, Shikida M, Ogura D and Sato K 2007 Glove type of wearable tactile sensor produced by artificial hollow fibre 4th Int. Conf. on SolidState Sensors, Actuators and Microsystems TRANSDUCERS and EUROSENSORS (Lyon, France)

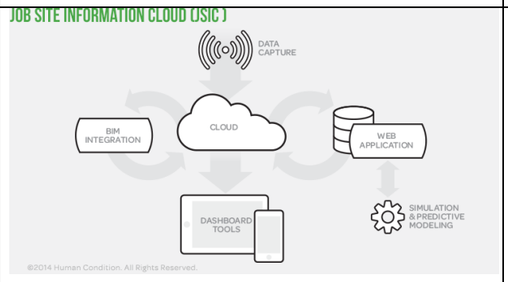
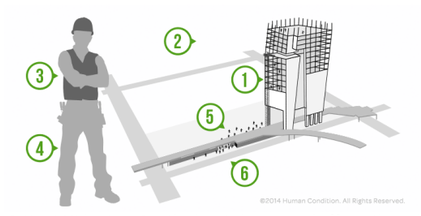
[251]. Hui Z, Ming T X, Xi Y T and Sheng L X 2006 Pressure sensing fabric Proc. MRS 920 0920S0505
[252]. Li L F and Ding Y S 2009 Design and analysis of parallel woven structurebased flexible resistive pressure sensor 3rd Int. Conf. on Bioinformatics and Biomedical Engineering ICBBE (Beijing)
[253]. Inaba M, Hoshino Y, Nagasaka K, Ninomiya T, Kagami S and Inoue H 1996 A fullbody tactile sensor suit using electrically conductive fabric and strings Int. Conf. on Intelligent Robots and Systems vol 2 pp 450–457.
[254]. Brady S, Diamond D and Lau K T 2005 Inherently conducting polymer modified polyurethane smart foam for pressure sensing Sensors Actuators A 119 398–40
[255]. Shimojo M, Namiki A, Ishikawa M, Makino R and Mabuchi K 2004 A tactile sensor sheet using pressure conductive rubber with electricalwires stitched method IEEE Sensors J. 4 589–96.
[256]. Bloor D, Donnelly K, Hands P J, Laughlin P and Lussey D 2005 A metal–polymer composite with unusual properties J. Phys. D: Appl. Phys. 38 2851–60
[257]. Hussain M 2001 Conductive rubber materials for pressure sensors J. Mater. Sci. Lett. 20 525–7.
[258]. Cho G, Jeong K, Paik M J, Kwun Y and Sung M 2011 Performance evaluation of textilebased electrodes and motion sensors for smart clothing IEEE Sensors J. 11 3183–93
[259]. Huang C T, Shen C L, Tang C F and Chang S H 2008 A wearable yarnbased piezoresistive sensor Sensors Actuators A 141 396–403.
[260]. Zhang H, Tao X M, Yu T X and Wang S Y 2006 Conductive knitted fabric as largestrain gauge under high temperature Sensors Actuators A 126 129–40
[261]. Gioberto G and Dunne L 2012 Theory and characterization of a topthread coverstitched stretch sensor Proc. IEEE Int. Conf. on Systems, Man and Cybernetics, SMC (Seoul, Korea)
[262]. Pacelli M, Caldani L and Paradiso R 2006 Textile piezoresistive sensors for biomechanical variables monitoring 28th Annu Int. Conf. on IEEE Engineering in Medicine and Biology Society EMBS (New York, NY)
[263]. Wijesiriwardana R, Dias T and Mukhopadhyay S 2003 Resistive fibremeshed transducers Proc 7th IEEE Int. Symp. on Wearable Computers ISWC (White Plains, NY)
[264]. Sawhney A, Agrawal A, Patra P and Calvert P 2006 Piezoresistive sensors on textiles by inkjet printing and electroless plating Proc. MRS 920 0920S0504
[265]. Kim K J, Chang Y M, Yoon S K and Hyun J 2009 A novel piezoelectric PVDF filmbased physiological sensing belt for a complementary respiration and heartbeat monitoring system Integr. Ferroelectr. 107 53–68
[266]. Carpi F, De Rossi D, Kornbluh R, Pelrine R and SommerLarsen P 2008 Dielectric Elastomers as Electromechanical Transducers ed F Carpi et al (Amsterdam: Elsevier) pp 134–5
[267]. Calvert P, Patra P, Sawhney A, Agrawal A and Duggal D 2007 Printed conducting polymer strain sensors for textiles 23rd Int. Conf. on Digital Printing Technologies (Anchorage, AK)
[268]. Kim H K et al 2003 Characteristics of electrically conducting polymercoated textiles Mol. Cryst. Liq. Cryst. 405 161–9.
[269]. Campbell T, Munro B, Wallace G and Steele J 2007 Can fabric sensors monitor breast motion? J. Biomech. 40 3056–9.
[270]. Lipomi D J, Lee J A, Vosgueritchian M, Benjamin C K, Bolander J A and Bao Z 2012 Electronic properties of transparent conductive films of PEDOT:PSS on stretchable substrates Chem. Mater. 24 373–82
[271]. Liu N, Fang G, Wan J, Zhou H, Long H and Zhao X 2011 Electrospun PEDOT:PSSPVA nanofibre based ultrahighstrain sensors with controllable electrical conductivity J. Mater. Chem. 21 18962–6

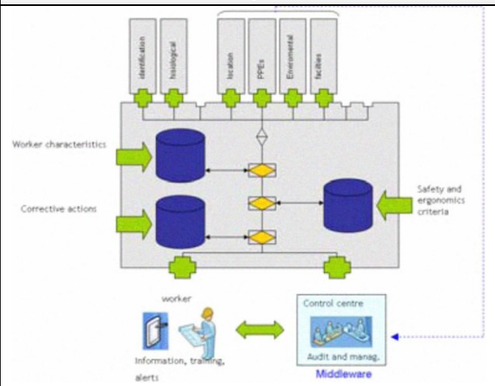
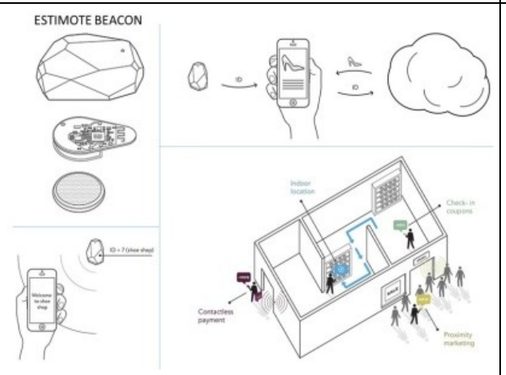
[272]. Ding Y, Invernale M and Sotzing G 2010 Conductivity trends of PEDOTPSS impregnated fabric and the effect of conductivity on electrochromic textile ACS Appl. Mater. Interfaces 2 1588–93
[273]. Wu J 2004 Synthesis, characterization and applications of conducting polymer coated textiles Dissertation University of Wollolong.
[274]. Fan Q, Zhang X and Qin Z 2012 Preparation of polyaniline/polyurethane fibres and their piezoresistive property J. Macromol. Sci. B 51 736–46
[275]. Shirinov A V and Schomburg W K 2008 Pressure sensor from a PVDF film Sensors Actuators A 142 48–55.
[276]. Wang Y R, Zheng J M, Ren G Y, Zhang P H and Xu C 2011 A flexible piezoelectric force sensor based on PVDF fabrics Smart Mater. Struct. 20 045009
[277]. Yang W, Torah R, Yang K, Beeby S and Tudor J 2012 A novel fabrication process to realize piezoelectric cantilever structures for smart fabric sensor applications IEEE Sensors Conf. (Taipei, Taiwan)
[278]. Krishna G M and Rajanna K 2004 Tactile sensor based on piezoelectric resonance IEEE Sensors J. 4 691–7.
[279]. Edmison J, Jones M, Nakad Z and Martin T 2002 Using piezoelectric materials for wearable electronic textiles Proc. 6th Int. Symp. on Wearable Computers ISWC (Seattle, WA)
[280]. Schwodiauer R, Ortwein C, Buchberger G, Graz I, Bartu P and Bauer S 2008 Flexible touchand pressure sensitive piezo elastomer stretch sensor for simple surface position detection 13th Int. Symp. on Electrets ISE13 (Tokyo, Japan).
[281]. Kogler A, Buchberger G, Schwodiauer R and Bauer S 2011 Ferroelectret based flexible keyboards and tactile sensors 14th Int. Symp. on Electrets ISE (Montpellier, France)
[282]. Rothmaier M, Luong M and Clemens F 2008 Textile pressure sensor made of flexible plastic optical fibres Sensors 8 4318–29.
[283]. Tao X M, Tang L Q, Du W C and Choy C L 2000 Internal strain measurement by fibre Bragg grating sensors in textile composites Compos. Sci. Technol. 60 657–69
[284]. ElSherif M A, Yuan J and MacDiarmid A 2000 Fiber optic sensors and smart fabrics J. Intell. Mater. Syst. Struct. 11 407–14.
[285]. FernandezValdivieso C, Matias I R and Arregui F J 2002 Simultaneous measurement of strain and temperature using a fibre Bragg grating and a thermochromic material Sensors Actuators A 96 21–4
[286]. Li Y L, Chen S Y, Yang L H and Cao L H 2011 Study on threedimension computer simulation of plain knitted fabrics Adv. Mater. Res. 213 595–9
[287]. Little A F and Christie R M 2010 Textile applications of photochromic dyes. Part 2: factors affecting the photocoloration of textiles screenprinted with commercial photochromic dyes Color. Technol. 126 164–70
[288]. Van der Schueren L, De Clerck K, Brancatelli G, Rosace G, Van Damme E and De Vos W 2011 Novel cellulose and polyamide halochromic textile sensors based on the encapsulation of methyl red into a sol–gel matrix Sensors Actuators B 162 27–34
[289]. Dashti M, Mokhtari J, Nouri M and Shirini F 2012 Imparting conductivity and chromic behaviour on polyester fibres by means of poly(3methylthiophene) nanocoating J. Appl. Polym. Sci. 124 3007–12
[290]. Akcelrud L 2003 Electroluminescent polymers Prog. Polym. Sci. 28 875–962
[291]. Molina J, Esteves M F, Fernandez J, Bonastre J and Cases F 2011 Polyaniline coated conducting fabrics, chemical and electrochemical characterization Eur. Polym. J. 47 2003–15

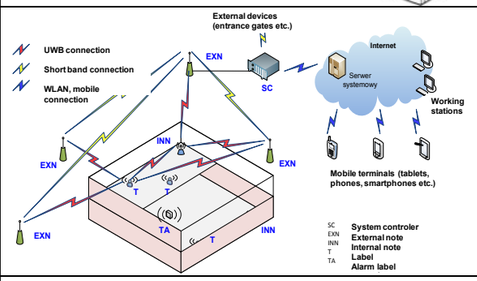
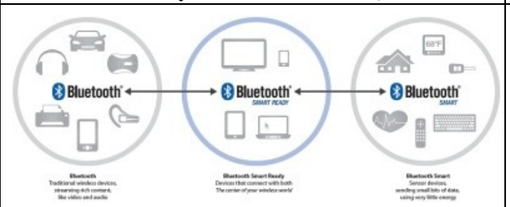
[292]. Torsi L, Pezzuto M, Siciliano P, Rella R, Sabbatini L, Valli L and Zambonin P G 1998 Conducting polymers doped with metallic inclusions: new materials for gas sensors Sensors Actuators B 48 362–7
[293]. Hong K H, Oh K W and Kang T J 2004 Polyanilinenylon 6 composite fabric for ammonia gas sensor J. Appl. Polym. Sci. 92 37–42
[294]. Collins G E and Buckley L J 1996 Conductive polymercoated fabrics for chemical sensing Synth. Met. 78 93–101
[295]. Kwon O S, Park E, Kweon O Y, Park S J and Jang J 2010 Novel flexible chemical gas sensor based on poly(3,4ethylenedioxythiophene) nanotube membrane Talanta 82 1338–43
[296]. Lu H H, Lin C Y, Fang Y Y, Hsiao T C, Ho K C, Yang D and Lin C W 2008 NO gas sensor of PEDOT: PSS nanowires by using direct patterning DPN Proc. 30th Annu. Int. Conf. IEEE Engineering in Medicine and Biology Society, Personalized Healthcare through Technology (Vancouver, Canada).
[297]. Jin G, Norrish J, Too C and Wallace G 2004 Polypyrrole filament sensors for gases and vapours Curr. Appl. Phys. 4 366–9
[298]. Bai H and Shi G 2007 Gas sensors based on conducting polymers Sensors 7 267–307
[299]. Seesaard T, Lorwongtragool P and Kerdcharoen T 2012 Wearable electronic nose based on embroidered amine sensors on the fabric substrates 9th Int. Conf. on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTICON (Hua Hin, Thailand)
[300]. Shim B S, Chen W, Doty C, Xu C L and Kotov N A 2008 Smart electronic yarns and wearable fabrics for humanbiomonitoring made by carbon nanotube coating with polyelectrolytes Nano Lett. 8 4151
[301]. Bowman D and Mattes B R 2005 Conductive fibre prepared from ultrahigh molecular weight polyaniline for smartfabric and interactive textile applications Synth. Met. 154 29
[302]. Tung A T, Park BH, Liang D H and Niemeyer G 2008 Lasermachined shape memory alloy sensors for position feedback in active catheters Sensors Actuators A 147 83–92
[303]. Shojaei A, Li G and Voyiadjis G Z 2012 Cyclic viscoplasticviscodamage analysis of shape memory polymers fibers with application to selfhealing smart materials J. Appl. Mech. 80 1
[304]. Stylios G K and Wan T 2007 Shape memory training for smart fabrics Trans. Inst. Meas. Control 29 321–36

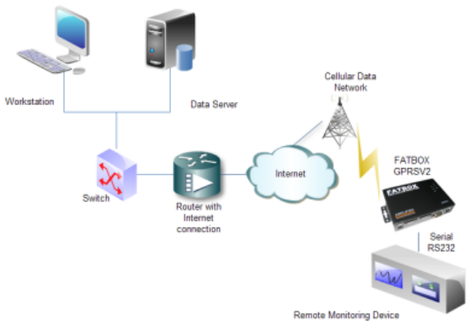
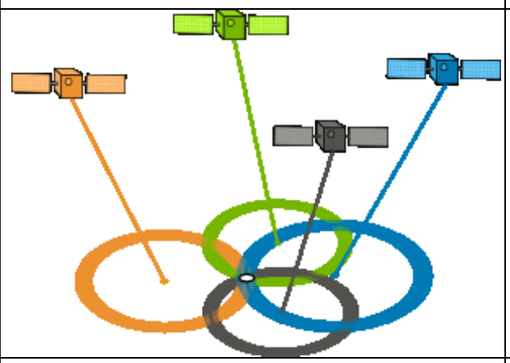
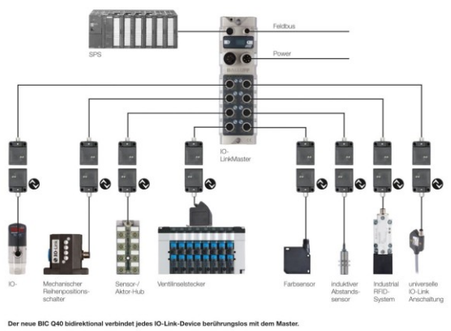
A List of electronic, textronic, mechatronic and ICT - based measures and technologies, which may potentially be used to develop safety - focused technical and organisational solutions in the smart working environment

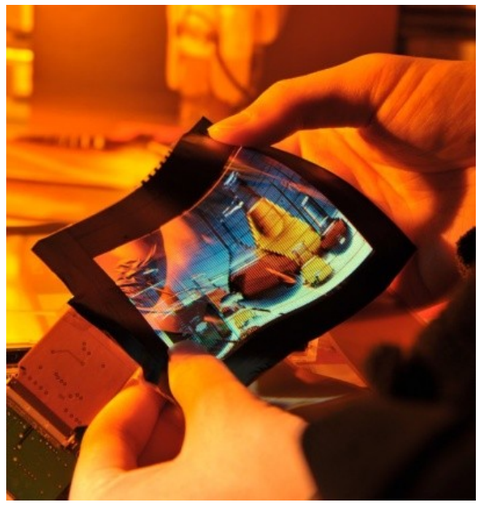
Annex to the report „An inventory of selected electronic, textronic, mechatronic and ICT-based solutions for safety-related applications in smart working environments"; authors: G. Gralewicz, G. Owczarek, CIOP-PIB, 2015, Warsaw, Poland

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
1	Hard hat and vest	[1,2] RAPIDS Construction Safety and Technology Laboratory		Project proposal – searching for contractors The hard hat and vest are equipped with real-time tracking technologies, which allow for location of the user inside and outside buildings, monitoring of his/her vital functions and movement (position), and monitoring of selected parameters of the work environment. User identification. The vest is fitted with a system of safety airbags, protecting users during falls. The hard hat and vest are supplied from power sources such as solar panels. Communication (data transmission) is provided at surveillance and decision-making levels. Technologies: – Real Time Location System (RTLS) – RFID – Bluetooth – GPS – Low Energy (BLE) – QR codes – Solar panels – Other	Alarm signals Real-time location inside and outside – Real Time Location System (RTLS) based on RFID, standard Bluetooth and GPS technologies Low Energy (BLE) Motion detection Automatic visual recognition based on QR codes Power supply from solar panels Fall protection using a system of protective airbags Monitoring of vital functions Exterior temperature monitoring Electric shock monitoring	Warning against hazards Detecting the presence of worker in dangerous zones Monitoring of worker' activity Monitoring worker' health parameters Monitoring work environment factors	*Worker level*	*Personal protective equipment (PPE)*
2	Software for data collection and analysis, and for supporting the decision process Job Site Information Cloud (JSIC)	[1,2] RAPIDS Construction Safety and Technology Laboratory	  1. Hoist Utilization Are the hoists being used efficiently and how do you eliminate bottlenecks? 2. Climate Factors How does weather affect worker movements? How does weather affect job site efficiency? 3. Smart Protective Gear Hard hats and safety vest enabled with sensors and wireless communications. 4. Worker Location Are the workers on time and in the right zone? 5. Predictive Alerting Will there be a future problem based on current worker and equipment movements? 6. Safety Alerting In the event of an emergency, did everyone get out of the building?	Data from sensors (workers activity, health parameters, work environment factors) are transmitted and processed on the server. Data can be accessed from client computers. Dangerous situations are foreseen basing on historical data and relevant mitigation procedures are started. Thanks to the monitoring of employee activity, works can be planned and coordinated in emergency situations.	Work time monitoring Automated reporting Resource planning SMS notifications Virtual 3D construction site Manager's dashboard	Information support Supporting decisions 3D modelling	*Management level*	*Technical measures* *Organisational measures*

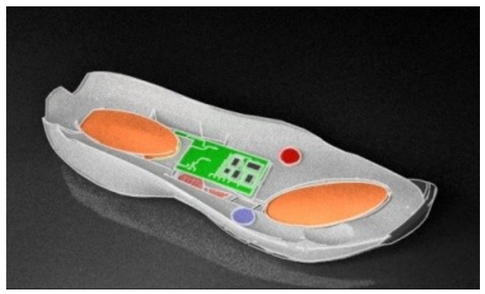
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
3	RFID technology	[5] OSALAN Basque Institute for Safety and Health		Automatic identification of durable objects, such as machines, personal protective equipment, monitoring of workers' activity in dangerous areas	Monitoring of personal protective equipment Location Identification of worker in dangerous areas	Monitoring of personal protective equipment Monitoring of worker' activity	M*anagement level*	*Technical measures*
4	IBeacon technology	[6] Apple, Inc.	 	iBeacon is a Bluetooth Smart-based standard, promoted by Apple and in a way competitive to NFC. iBeacon can detect distance between devices within a significantly wider range than in the case of NFC – from a few centimetres to 50–70 metres. NFC is capable of working in a range of a maximum of 10–20 centimetres. This allows for the implementation of accurate location systems in places where GPS is not sufficiently precise or has no coverage, like inside buildings.	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	M*anagement level* W*orker level*	*Technical measures*

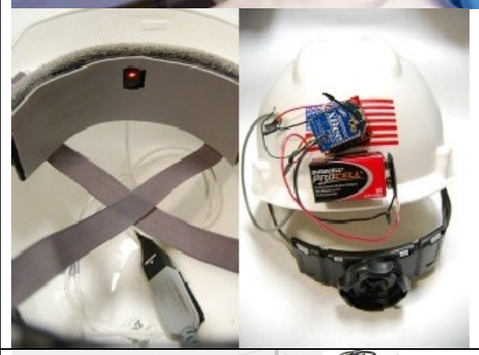
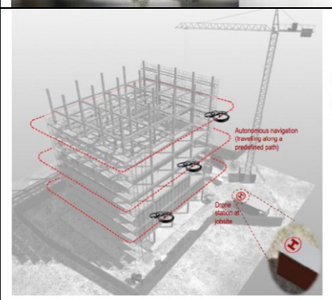
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
5	NFC – Near Field Communication technology	[7]	 	Near Field Communication, NFC – short-range, high-frequency, radio communication standard for wireless data exchange at a distance of 20 cm maximum. This technology is a simple extension of ISO/IEC 14443 (proximity card), combining smart card interface with a reader in a single device. NFC devices can communicate with existing equipment following the ISO/IEC 14443 standard (cards and readers) and with other NFC devices.	Identification of worker Access authorisation Monitoring of worker' activity Identification of tools and safety points	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	*Worker level*	*Personal protective equipment (PPE)*
6	UWB – Ultra WideBand technology	[8,9]		UWB is a developing wireless communication technology, characterised by high data transmission rates (up to 2 Gb/s) at small distances (of approximately 10 m). UWB works at low power levels, thus eliminating interference with other radio communication systems and providing for the construction of devices with low energy consumption. Despite a fast drop in transmission rates with increasing distance, UWB has good chances of replacing cables between office or home equipment in the near future. The system works in the 3.1–4.85 GHz and 6.2–9.7 GHz (Direct Spread UWB) or 3.1–10.6 GHz (Multi Band OFDM) bands.	Wireless data exchange Detecting the presence of worker in dangerous zones Monitoring of worker' activity	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	*Management level*	*Technical measures*
7	Bluetooth technology	[10]		It is an open standard specified in IEEE 802.15.1. Bluetooth specification covers three transmitter power classes 1–3, with a range of 100, 10 and 1 metre in the open space. The most popular class is 2. This technology uses radio waves in ISM2.4 GHz band.	Wireless data exchange	Communication	*Management level* *Worker level*	*Technical measures*

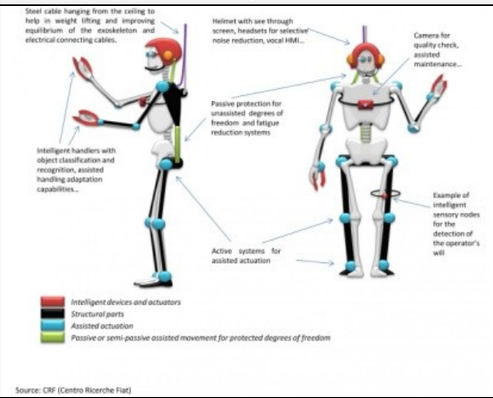
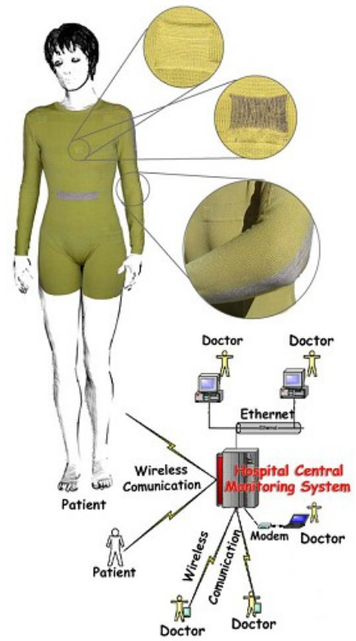
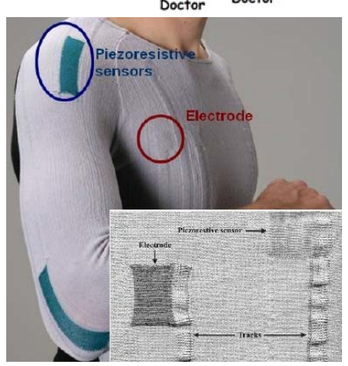
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
8	ZigBee technology	[11,12]		ZigBee based networks are characterised by low energy consumption, low bit-rates (up to 250 kbps) and a range between nodes of approximately 100 m. Typical applications include sensor networks, personal networks (WPAN), home control systems, alarm and monitoring systems.	Wireless data exchange	Communication	*Management level* *Worker level*	*Technical measures*
9	GPRS – General Packet Radio Service technology	[13]		A technology related to packet data transmission in GSM networks. The actualtransmission rates of 30–80 kb/s allow for using the internet or audio/videostreaming. The user pays for the actual number of bytes sent or received and not for the time of the connection being active. GPRS is often referred to as a 2.5G "technology" because it is a step in the evolution of GSM (as a second generation of mobile telephony) to the 3G standard network.	Wireless data exchange	Communication	*Management level* *Worker level*	*Technical measures*
10	GPS – Global Positioning System technology	[14]		It works using the principle of measuring radio signal travel times from satellites to the receiver. Knowing the electromagnetic wave speed and the exact time of sending a specific signal, the distance from the receiver to the satellites can be measured. The GPS signal contains information about the geometry of the satellites in the sky ("almanac") and information about their theoretical path and deviations from this path ("ephemeris"). A GPS receiver first updates these data in its memory and uses the further part to establish its distance from specific satellites whose receivers are within its range. By making a spatial linear set-out, the receiver's microprocessor can calculate the geographical location (longitude, latitude and ellipsoidal height) and then present it in a selected datum (typically, WGS 84) and specify the current GPS time very precisely.	Location	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	*Management level* *Worker level*	*Technical measures*
11	IO-Link technology	[15]		IO-Link is a universal interface which unifies many diverse standards currently applied in automation systems. It allows for full communication between control systems, sensors and actuators via a 3-wire cable. It is fully compatible with all communication protocol standards used in the industry. Elements equipped with the IO-Link interface provide remote access to detailed diagnostic information and current process data, and allow for the adjustment of sensor parameters to current production requirements.	Communication	Communication	*Machinery level*	*Technical measures*

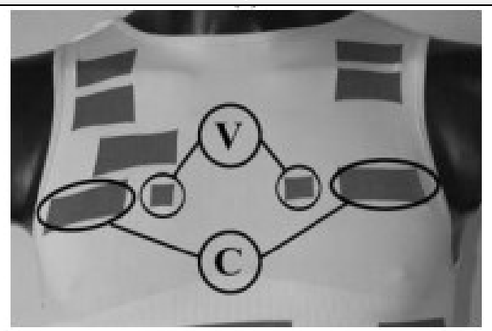
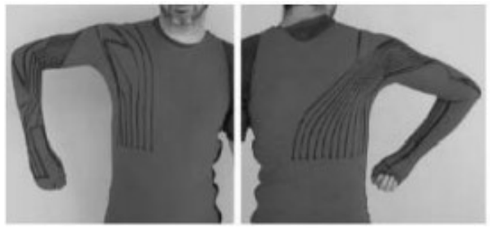
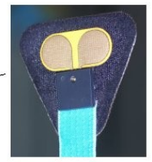
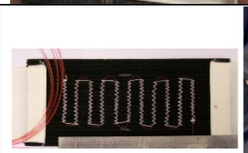
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
12	OLEDs – Organic light-emitting diodes technology	[16]		OLED consists of an emission layer, conductivelayer, a substrate and an anode and cathode. Layers are composed of organic particles of conductive polymers. The level of conductivity of those materials locates them between insulators and conductors, therefore sometimes they are called organic semiconductors. When voltage is applied to OLED, electrons start to flow from cathode to anode, hence the cathode provides electrons to the emission layer and the anode takes them from the conductive layer. In other words, the anode serves electron holes to the emission layer. When a junction is biased in the direction of conduction, the emission layer is negatively charged while the conductive layer becomes rich in positively charged holes. Electrostatic interaction attracts electrons and holes, which recombine with each other. This happens close to the emission layer because holes in organic semiconductors are more mobile than electrons (contrary to the case of non-organic semiconductors). During recombination, the electron passes to a lower energy level, which is accompanied by electromagnetic radiation emission in the visible spectrum. That is why this layer is called "emission layer". OLED does not emit light in reversed biased conditions of the junction because the electron holes move towards the anode and electrodes to the cathode, so they drift apart and do not recombine. ITO (Indium Tin Oxide – a solid solution of indium(III) oxide and tin(IV) oxide) is usually used as a material for the anode. It is transparent for light and has high work on output, which facilitates the movement of holes to the polymer layer. Metals such as aluminium and calcium are often used to create cathodes because of their low work on output, which facilitates the injection of electrons to the polymer layer.	Visualisation, display Communication	Information support for worker	W*orker level*	*Personal protective equipment (PPE)*
13	XOEye technology	[17,18,19] XOEye Technologies		An 8-megapixel camera built into spectacle frames (which allows for recording movies), integrated earphones and microphone, built-in gyroscope and accelerometer. Powerful and efficient ARM processor, WiFi connection, Linux and integrated Java technology ANSI safety certificate.	Information support for worker Monitoring of employee position Video recording of work performance Training	Information support for worker Training	W*orker level*	*Personal protective equipment (PPE)*
14	Google Glass Technology	[20] Google Inc.		Google Glass are glasses with augmented reality features created by Google. The glasses have the same functions as a typical smartphone, but they are operated by voice commands using natural language processing. Specification: Android 4.0.4 OS or higher 640x360 screen 5-megapixel camera, which allows for recording 720p movies 16 GB memory (12 GB for the user) 2 GB RAM (682 MB previously) Wi-Fi 802.11b/g Bluetooth micro USB connection bone conduction of sound waves	User information support Communication Video recording Speech recognition Video and audio playback	Information support for worker Training	W*orker level*	*Personal protective equipment (PPE)*

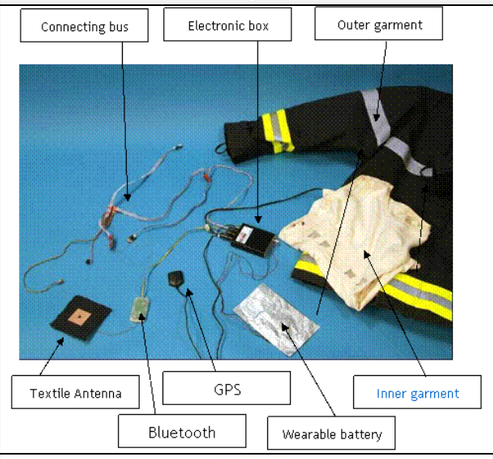
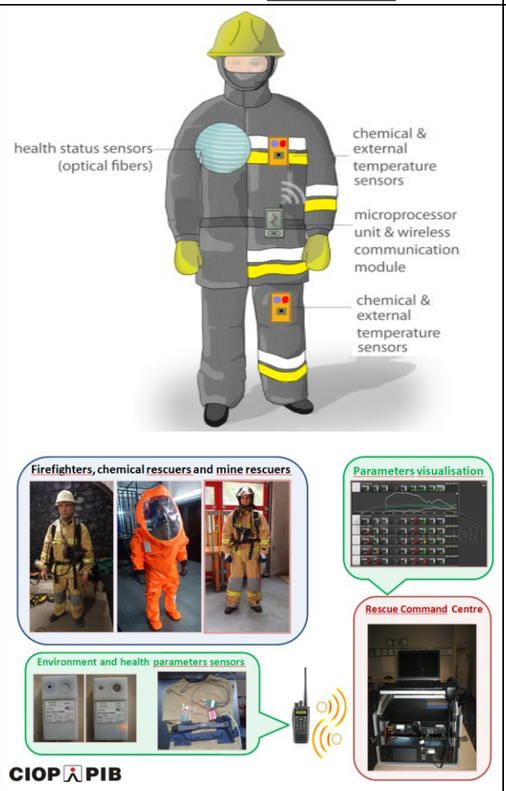
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
15	Vuzix Corporation's M100 Smart Glasses technology	[21] Vuzix Corporation	 	Vuzix Corporation's M100 Smart Glasses are fitted with a WQVGA display module. They offer most of the functions and applications of a modern smartphone. Specification: TI OMAP 4430 CPU speeding up to 1 GHz, 1 GB RAM, 4 GB built-in memory, 720p camera and GPS, Wi-Fi and Bluetooth modules. Android 4.0 Ice Cream Sandwich.	User information support Communication Video recording Speech recognition Video and audio playback	Information support for worker Training	W*orker level*	*Personal protective equipment (PPE)*
16	M2000AR	[22] Vuzix Corporation		M2000AR was created for industrial applications. It consists of a hands-free module and a 720p HD display. It can be used as an information support tool for an employee or for training purposes.	User information support Communication Video recording Speech recognition Video and audio playback	Information support for worker Training	W*orker level*	*Personal protective equipment (PPE)*
17	DataGlove™ VRLOGIC technology (Stretch Sensors)	[23] VRLOGIC GmbH		Stretch sensors in the glove detect the user's hand motions (2 sensors for each finger). System interface – an USB cable (platform independent) connection to a computer and a wireless Ultra Set 5DT Data Glove interface providing a Bluetooth connection with a computer (up to 20m).	Communication - design and optimisation support in the 3D virtual reality Control	Communication 3D modelling	M*anagement level*	*Technical measures*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
18	ElekTex® technology ElekTex Smart Fabric Controls Textile keyboards using pressure sensors	[24] Eleksen Ltd.		ElekTex® is a combination of conductive fibres and nylon. Pressure sensors help determine the XY position.	Control	Communication	W*orker level*	*Personal protective equipment (PPE)*
19	Verb for Shoe technology	[25] Vectra Sense		Footwear detects the activity level and automatically adjusts to improve comfort and performance. This is done using a built-in computer, which learns individual motion patterns and suitably adjusts the shoe. The computer also allows for wireless data transmission and sharing information with other users of this type of footwear. A ShoeDoctor application is also available, which actively monitors energy consumption and performance of the air blister system and analyses the user's motion.	Monitoring user's activity Analysing user's movements and adapting to the conditions Communication and data exchange	Monitoring of worker' activity Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
20	BodyMedia SenseWear system	[26] BodyMedi, Inc.		The SenseWear band works as a multifunctional monitor which allows for the collection and analysis of health data. The band measures the following parameters: movement, number of steps, skin's electrical conductivity, skin temperature, amount of heat lost by the organism.	Measuring movement, counting steps, measuring skin's electrical conductivity, skin temperature and the amount of heat lost by the organism	Monitoring employee health parameters	W*orker level*	*Personal protective equipment (PPE)*
21	C-THRU – firefighter's helmet	[27] omerh.com		Firefighter's helmet with equipment: - thermal camera - 3D projector (augmented reality) - speakers and a microphone – communication - LED signal of air level in the bottle - wireless data transmission	Monitoring health parameters Monitoring environmental parameters Information support	Monitoring worker' health parameters Monitoring environmental parameters Information support for worker	W*orker level*	*Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
22	Helmet equipped with a sensor indicating the initial state of carbon monoxide poisoning	[28,29] Virginia Polytechnic Institute and State University	 	An integrated sensor indicating the initial state of carbon monoxide poisoning (pulse oximetry sensor) in a typical safety hard hat construction, providing for continuous and non-invasive monitoring. Test results have shown that the hard hat's users will be warned of imminent carbon monoxide poisoning with the accuracy of more than 99%.	Monitoring the initial state of carbon monoxide poisoning	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
23	Drone technology	[30,31,32, 33]	 (a) Autonomous navigation using predefined paths or locations  (b) Voice interaction between workers and the drone  (c) Safety manager interacts with workers using the drone and through the iPad 	Proposal for using the drone technology in construction industry. Drones can be piloted remotely using a smartphone, tablet or computer. Drones are fitted with video cameras which allow real-time viewing of places at the construction site and a can provide a source of archive materials for further use. Recommendations were given concerning inspections carried out using this tool. Three features were pointed out: Autonomous navigation: Safety managers shall have the possibility of controlling the device manually or using the autonomous navigation function. The latter can be done using predefined paths and places, with or without minimum user's interference. Voice interaction: Safety managers shall have the possibili1ty of talking to worker at their workplace with the use of the drone. In emergency situations, this feature shall allow them to communicate relevant orders before they can actually get to the place of accident. Improvement in battery lifetime: AR-Drone batteries allow for 13 minutes of flight. This period shall be increased to provide for longer flying times.	Carrying out safety inspections Information support for worker Monitoring work environment parameters Carrying out building inspections, e.g. energy audits of buildings Monitoring of pipeline tightness	Information support Supporting decisions Information support for worker Monitoring work environment parameters	M*anagement level*	*Technical measures*

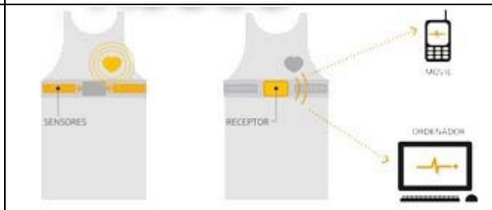
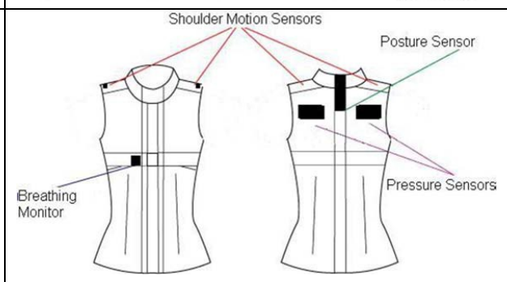
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
24	Robo-Mate project	[34,35,36]	 Source: CRF (Centro Ricerche Fiat)	Man-robot exoskeleton for manual operation in different industrial areas. The main idea is to provide a smart tool for workers which could improve performance and reduce the physical stress or even limit damages. Object recognition and classification system – smart hands. Helmet with noise reduction, a screen and communication with an HMI. Camera registering the quality of performed work. System of active sensors monitoring the worker's positions and supporting actuators.	Increasing physical work performance while reducing loads on the muscle and bone system at the work station Information support for worker Monitoring of employee position Video recording of work performance	Monitoring of worker' activity Monitoring worker' health parameters Information support for worker	W*orker level*	*Personal protective equipment (PPE)*
25	Wealthy project	[37] Smartex s.r.l See also: [38-63]	 	The project consisted in the development of a health monitoring system based on "wearable electronics", made by integrating smart sensors (in the form of fibres and yarn), advanced signal processing technologies and modern telecommunication systems of a textile platform. This solution can be used by cardiology patients during rehabilitation, worker performing tasks in hazardous work environments and by healthcare workers.	Monitoring of health parameters (strain gauges – respiration monitoring, activity sensors).	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

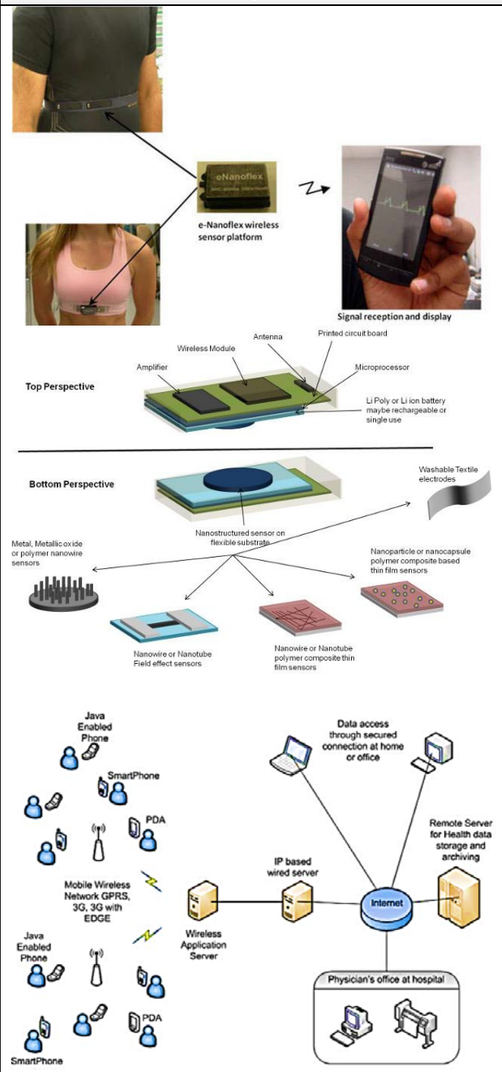
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
26	MY HEART project	[64] See also: [65-77]	 	This project covered the development of smart biomedical garments for preventive use during customised therapies of certain user groups. Fields of application: Improvement of physical activity: CardioActive Improvement of food and dietary patterns: CardioBalance Sleep and relaxation phase monitoring: CardioSleep Solutions for coping with stress: CardioRelax Early diagnosis and forecasting of dangerous incidents: CardioSafe	Monitoring health parameters	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
27	ConText project	[78] See also: [79-86]	 	The aim of the project was to create a system in which different sensors are introduced into textiles in order to ensure constant monitoring of vital parameters. Sensors were designed for the measurement of the EMG signal. The sensors were integrated with textiles – thus creating a prototype vest.	EMG signal measurements	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
28	OFSETH project	[87] See also: [88-96]	  **Figure 2-3: Elastic bandage with stitched fibre** 	The project focuses on optical fibre technology for the monitoring of health parameters. The following items were developed: Breath sensor. NIRS-based SpO_2 sensor	Breath and SpO_2 monitoring controls the level of patient's blood saturation and the following changes in blood volume in skin	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
29	PROETEX project	[97] See also: [98-112]		The project will cover the development of smart clothing for emergency personnel aimed at improving their safety. The following items were developed: heart rate, breath, temperature sensors, exterior threat detection system (2 accelerometers), power supply control system, communication system (textile antenna, Bluetooth), positioning system (GPS SMA), threat signalling system (sound and light). Gas detectors are used in footwear. A set for civil workers was also developed, consisting of heart rate, breath and temperature sensors. Remote monitoring is performed using software which processes and visualises data from the system of sensors.	Monitoring health parameters Monitoring environmental parameters Information support	Monitoring worker' health parameters Monitoring environmental parameters Information support for worker	W*orker level*	*Personal protective equipment (PPE)*
30	iProtect project	[113]		The main objective of the project was the development of an advanced smart system of personal protective equipment intended for users performing professional tasks in complex work environments with a high risk of exposure to harmful and dangerous factors, i.e. during fire-fighting operations, rescue operations performed by chemical rescue workers and rescue workers in hard coal mining plants. The project is divided into four consecutive phases: 1) development of the concept and technical and operating requirements for the new PPE system, 2) development and integration of technical elements monitoring selected physiological parameters of humans (optical fibre-based sensors for measurements of body temperature, heart rate and breathing rate), monitoring environmental condition during the performance of professional tasks (exterior temperature sensors, gases: oxygen, carbon monoxide and dioxide, methane, ammonia, chlorine) and a system of communication which collects and transmits measurement data from the sensors to the monitoring subsystem and later to the rescue operation command centre, 3) verification and validation of the developed modules and the entire system by performing operating tests in order to assess their operation in real conditions, 4) dissemination of the results of completed research and development works by publishing scientific and popular science articles, participation in global conferences and seminars, preparing information brochures and organising seminars for manufacturers and distributors of personal protective equipment during specialist fairs and exhibitions. The results of this project are addressed to the chemical rescue workers, fire brigades and rescue workers in underground mining plants. Relevant modules with gas and temperature sensors, including a special wireless communication system, were developed. They jointly form a system aimed at detecting noxious gases and elevated temperatures in work environments during rescue operations. One of the project's results is a module of sensors for the monitoring of user's physiological parameters (body surface temperature, heart rate). The monitored work environment and physiological parameters are transmitted via a special communication system to the rescue operation coordination centre in order to ensure supervision of the operation, which is also the result of the project. The use of nanomaterials allowed for the development of indicators for noxious gases, electrically conductive trails and textile materials with electrostatic discharge safe properties.	Monitoring health parameters Monitoring environmental parameters Information support	Monitoring worker' health parameters Monitoring environmental parameters Information support for worker	W*orker level*	*Personal protective equipment (PPE)*

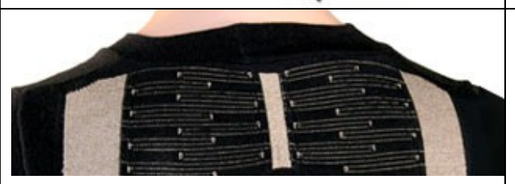
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
31	Smart clothing for firefighters' safety	[114] Viking	 	Thermal sensors are integrated into interior and exterior layers of the protective garment's textile. Monitor exterior temperature near the firefighter and on the interior layer adherent to the skin. Two LED displays are attached to the sensors – one on the sleeve and the other one on the back. The LED display on the upper part of the left shoulder is visible to other firefighters in the team and warns of potentially dangerous situations. The LED display on the sleeve indicates a dangerous heat level, both inside and outside the protective clothing. Sensors are covered with flexible, waterproof plastic coating, which provides protection against fluids. When exterior temperature reaches approx. 482ºF (250°C), the circle on the display starts flashing slowly. At 662ºF (350ºC), the display flashes faster. When temperature inside clothing reaches approx. 122ºF (50°C), a long line on the display will start flashing slowly at 156ºF (67ºC). It flashes quickly when temperature inside, close to the skin, reaches 174ºF (79ºC) – it is a dangerous situation. All elements comply with current standards for firefighting equipment. Microelectronics is durable and should last for at least 25 washing cycles. The only thing to remember about before washing is to remove the battery.	Monitoring health parameters Monitoring environmental parameters Information support	Monitoring worker' health parameters Monitoring environmental parameters Information support for worker	W*orker level*	*Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
32	Cooling Vests technology	[115] ClimaTech		Cooling vests have pockets for cold packs. Before usage, the packs must be stored in a fridge. A solution intended for industrial applications was also created, with compressed air acting as the cooling agent – the vest is connected to an air supply duct used at work stations for painting, sanding, welding etc.	Ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*
33	SmartSkin technology	[116] Natick		SmartSkin, the material used to make the diving suit, absorbs cold water, which expands and closes the gaps at hands, legs and neck, preventing or allowing the flow of water. Water trapped in the suit heats in contact with the body. When water heats up to the transition temperature specified by a part of the thermally-sensitive polymer hydrogel, more water can rinse the suit and cool its user. This passive system ensures continuous interior temperature control.	Ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*

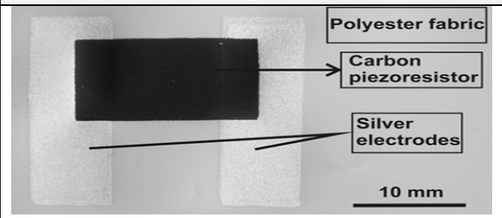
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
34	LifeShirt technology	[117,118] Vivonoetics		The LifeShirt set is light and machine-washable. It contains integrated sensors: of breath (sensing elements in the patient's torso and abdomen area), single-channel ECG sensor, triaxial accelerometer to monitor the posture and level of activity. The set can be optionally fitted with devices for measuring blood pressure, EEG, temperature and oxygen saturation in blood. Measurement data are automatically stored on a memory card and can later be analysed using dedicated software.	Monitoring health parameters	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
35	Shirt with a wireless sensor network to monitor patients	[119] Carlos III University of Madrid		The shirt is equipped with GPS, so the personnel knows exactly where the patient is located at a given moment. It also features an accelerometer, which determines whether the patient is standing, walking, running or lying. Furthermore, shirts are fitted with a series of alarm devices with default configuration settings, which are activated when certain parameters exceed initially set limits, e.g. 38ºC or 100 heart beats per minute. Alarms can be modified by physicians in order to adjust them to the specific needs of a given Patient.	Monitoring health parameters associated with location	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
36	Shirt with a polypyrrole and polyurethane composite sensor	[120] University College Dublin		Shirt for medical applications using a sensor made of polyurethane foam covered with polypyrrole. The purpose of using the shirt is to record breathing and movements of shoulders and the neck. Deep breathing creates a sine wave of resistance, which is the result of operation of the sensor made of the polypyrrole and polyurethane (PU) composite. The polyurethane foam covered with polypyrrole can play the role of a sensor for testing the frequency of breathing and detecting body motion.	Monitoring health parameters	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

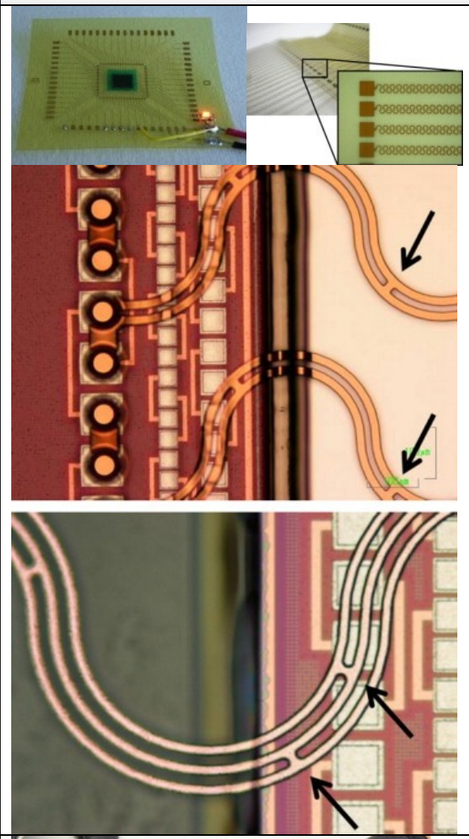
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
37	e-Nanoflex Sensor System technology	[121] University of Arkansas		Wireless textile-based health-monitoring sensor for athletes. The sensor contains a series of nanostructural textile sensing elements integrated with a standard sports bra. These sensors are smaller than a 2PLN coin, include golden nanowires and flexible nanosensors woven into the accompanying material. The nanowires are approximately 1 micrometre long and have diameters ranging from 20 to 200 nanometres. Thanks to the use of a special IT platform, the monitored data can be sent in real time to a physician, hospital or another person who has a smartphone.	Monitoring health parameters of athletes	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
38	Adidas Micoach Elite technology	[122] Adidas		This solution provides coaches and physicians with real-time, detailed information about the condition of football players. It measures speed, acceleration, distance covered, position in the field, heartbeat and energy used during the activity. Measurements of each movement, step and heartbeat are sent to the coach standing at the sideline of the field within one second. The technology used allows for better understanding of the physical and physiological effort of the team and individual players during matches and practice. By providing the possibility of in-depth analyses and trend observations, the Adidas Micoach Elite system can help reduce the risk of overtraining and injuries.	Monitoring health parameters of football players	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
39	NuMetrex Cardio shirt	[123,124] Textronics, Inc.		The shirt fits closely to the body. It records heartbeat and sends it to a compatible watch using a small transmitter located in the shirt's pocket. The shirt is made of special fibres, with high vapour permeability, and with an integrated pulse sensor. The manufacturer claims that measurements are not distorted by the changing temperature of the examined person or sweating because the sensor is adequately insulated. Results are collected using a sensor located in the shirt, and were initially intended for the monitoring of changes in the performance and for determining the maximum training loads for professional cyclists.	Pulse recording	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

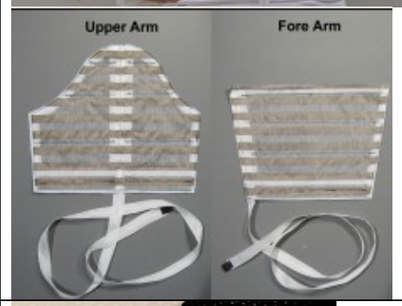
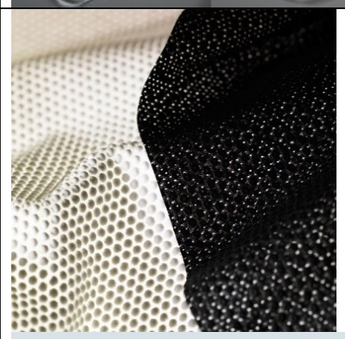
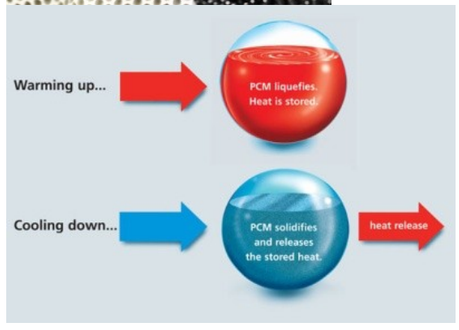
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
40	Jacket with thermal regulation system	[125] Grado Zero Espace srl		Cooling jacket – the internal cooling system consists of 50m of plastic pipes of 2mm in section.	Cooling – ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*
41	Jacket with the IOW (Intelligent Object to Wear) system	[125] Grado Zero Espace srl		Jacket with an internal heating system. The device monitors and adjusts body temperature in 4 different trunk areas (shoulders, torso, back). Heating pads are located in the lower part of the back, shoulders and torso. Temperature can be controlled using software provided on a CD.	Heating – ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*
42	WARMx technology	[126] warmX GmbH	 	WarmX is the manufacturer and distributor of heated textile used to make underwear. The company has its own globally patented technology for heating textiles, known as "warmX-technology". The underwear is made of a silver-fibre textile. Heating areas are located on the torso and neck, supplied from a battery installed at the waist.	Heating – ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*

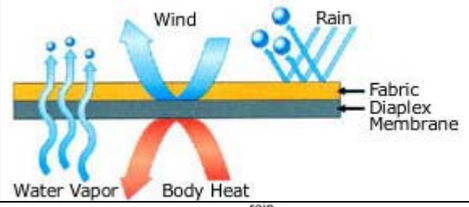
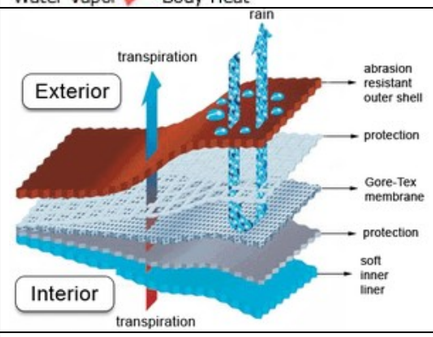
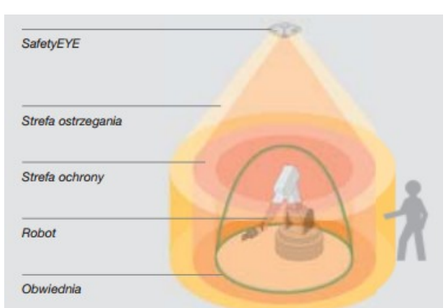
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
43	Link Vest technology	[125] Grado Zero Espace srl	  	The reconfiguration vest is intended for EADS Airbus worker working in the technical department of airlines. Equipment: OQO application – providing step-by-step instructions based on a predefined checklist. HMD glasses – display developed by the R&D of Carl Zeiss to provide information support. Bluetooth keyboard and earphones – real-time communication and information exchange.	Information support	Information support for worker	W*orker level*	*Personal protective equipment (PPE)*

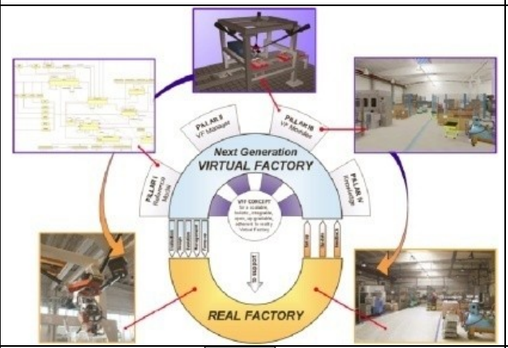
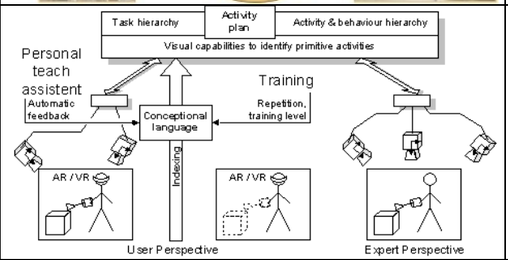
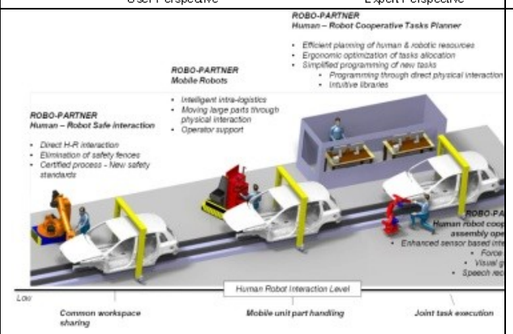
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
44	MICROFLEX project	[127,128]		Development of flexible materials – smart fabrics and textiles capable of detecting stimuli and responding or adjusting to them in a specific way.	Monitoring health parameters Monitoring environmental parameters	Monitoring worker' health parameters Monitoring work environment factors	W*orker level*	*Personal protective equipment (PPE)*
45	DEPHOTEX project	[129,131]	  	Research and development of flexible photovoltaic textiles based on new fibres.	Power supply – flexible supply systems	Power supply	c) *worker level*	*Personal protective equipment (PPE)*

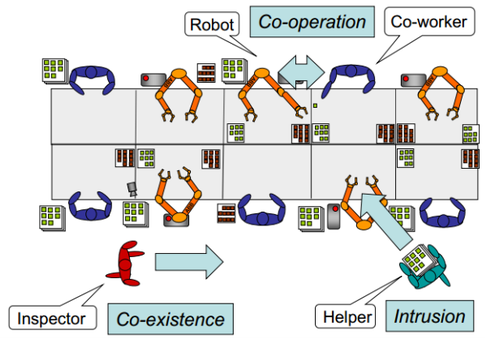
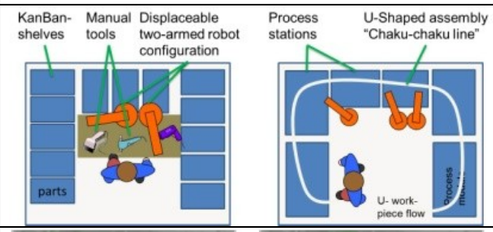
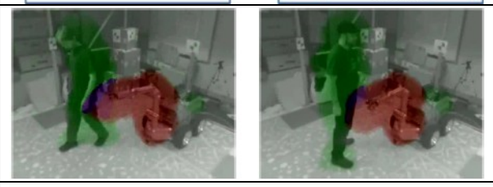
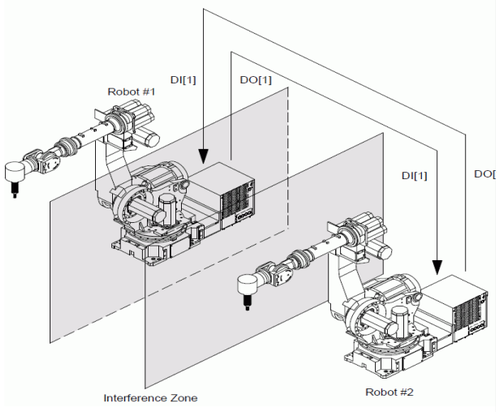
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
46	PLACE-it project	[132] See also: [133-139]		Development of a technological platform for light, thin and susceptible optoelectronic systems. Optoelectronic systems adapting to stretchable substrates, such as fabrics or films, large optoelectronic elements and zone connecting technologies.	Monitoring health parameters Signalling Lighting Flexible connections	Monitoring employee health parameters Warning against hazards	W*orker level*	*Personal protective equipment (PPE)*
47	Vibrotactile Feedback technology	[140]		Glove with an embedded vibration signal system, which, using appropriate vibration stimuli and different vibration patterns, can provide route information to a motorcycle rider without the need of looking at the navigation screen	Information support	Information support for worker	W*orker level*	*Personal protective equipment (PPE)*
48	EnableTalk technology	[141]		Glove capable of converting sign language to spoken language. EnableTalk is fitted with a comprehensive network of sensors which recognise hand motions and convert them to spoken words using a mobile telephone.	Information support	Information support for worker	W*orker level*	*Personal protective equipment (PPE)*

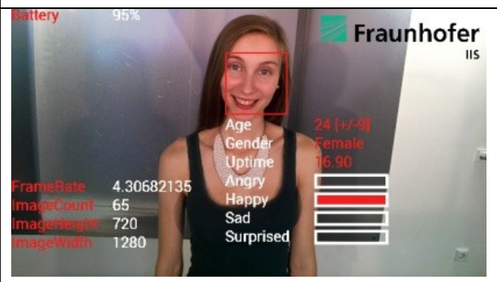
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
49	HÖVDING technology – an airbag for cyclists	[142] HÖVDING	 	Hövding is a bicycle helmet integrated with a collar (airbag). The collar is worn on the neck and it contains an airbag which is activated during an accident. The airbag is hood-shaped, it wraps up and protects the cyclist's head. The release mechanism is controlled by sensors, accelerometers and gyroscopes, which receive signals of irregular movements and respond to them.	Head protection	Protection	W*orker level*	*Personal protective equipment (PPE)*
50	MYONTEC – muscle performance and power monitoring	[143] Myontec	 	A system for muscle performance and power monitoring. It consists of trousers and a shirt integrated with sensors and special modules for measurements and data transfer. The trousers allow for the monitoring of different muscles, e.g. the quadriceps, tendon, calf.	Muscle performance and power monitoring	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*

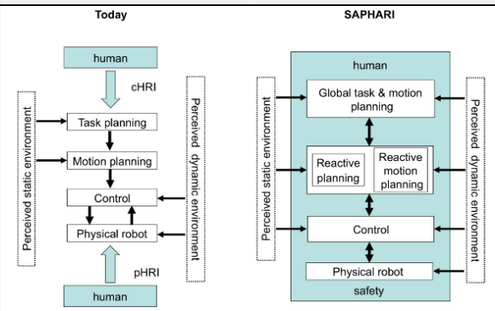
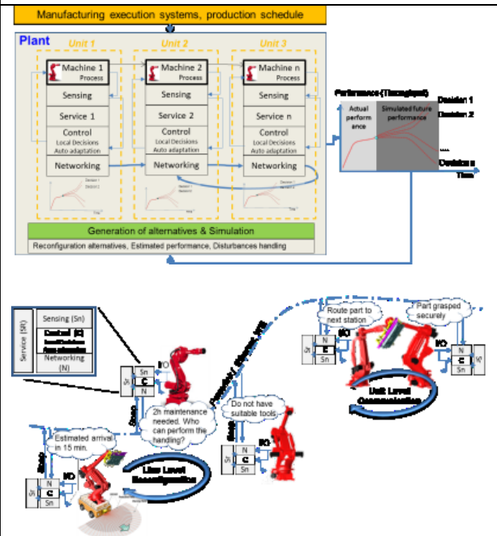
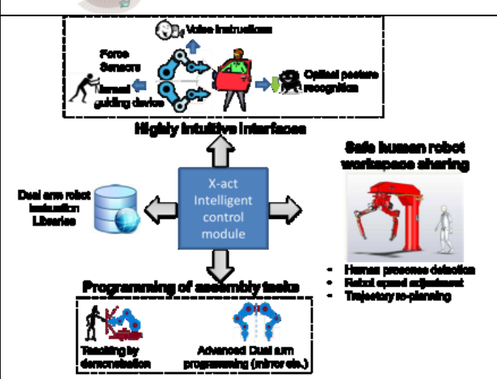
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
51	Shirt with pressure sensors – for violence detection and records	[144, 145]	 	The proposed system consists of garments or garments using smart fabrics with pressure sensors which classify and measure the intensity and amount of force used against the user's body.	Violence detection and recording	Monitoring worker' health parameters	W*orker level*	*Personal protective equipment (PPE)*
52	PCM – Phase Change Materials technology	[146] schoeller	 	Fabrics with an infinite number of tiny Phase Change Materials (PCM) microcapsules. Microcapsules respond to temperature differences by changing from solid to liquid state and vice versa. If body temperature or exterior temperature rises, the excess heat is stored. When temperature falls, the stored heat is emitted again.	Ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*

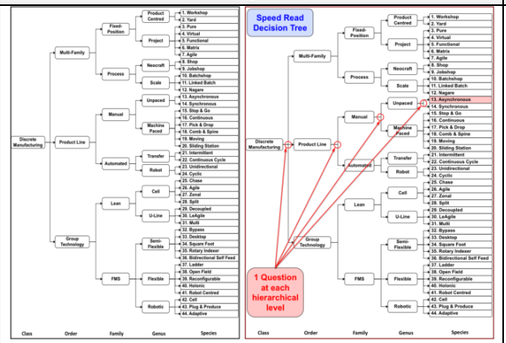
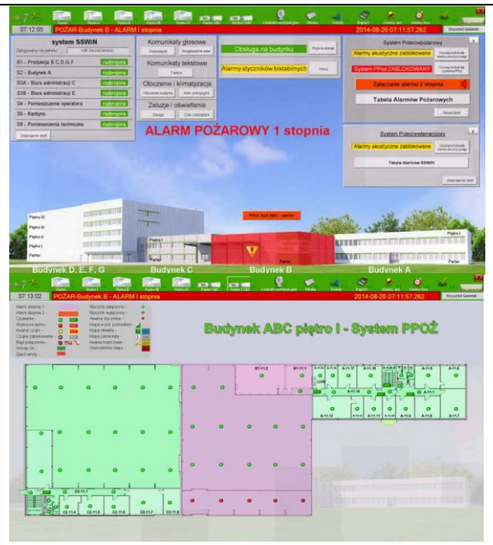
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
53	DiAPLEX technology	[147] Phenix		Waterproof, windproof and breathing "DiAPLEX" polyurethane membrane. It works basing on the principle of thermal vibrations and adapts to the surrounding environmental conditions. The membrane is composed of molecules whose volume changes with temperature – it lets excess heat and moisture through when temperature rises on the inner side of the garment by shrinking molecules, and reduces its permeability when interior temperature falls.	Ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*
54	Gore-Tex technology	[148] W. L. Gore & Associates (UK) Ltd.		Gore-Tex works using a semi-permeable membrane moulded in the fabric, made of porous Teflon. The microperforation is larger than single watermolecules which make up sweat transpired in vapour form but smaller than the multi-particle packets making up water in liquid state (e.g. rain). The difference in the concentration of water vapour on both sides of the membrane creates osmotic pressure, which facilitates the transport of water vapour from the medium with higher concentration to the lower concentration one, while the membrane remains impermeable to water.	Ensuring thermal comfort	Ensuring thermal comfort	W*orker level*	*Personal protective equipment (PPE)*
55	Noise Indicator NI-100	[149] 3M		The noise indicator from 3M™ is an easy to use, durable and cost-effective tool warning of noise level exceeding 85dB. It is one of the cheapest options for noise monitoring, enclosed in a solid, small and light casement. Easy to use. Easy to attach to a shirt or jacket. To switch it on, a button should be pressed and held until a green/red LED lights up. Battery allowing for up to 200 hours of operation without loading. It is considered one of the most innovative, high-quality and revolutionary ideas of popular science. It was listed among the 100 best products of 2011 and received the "Grand Award". The lithium-polymer battery can work for 200 hours without loading. Dimensions: 5.1cm (L) x 3.6cm (W) x 1.3cm (D) or 2"(L) x 1.4" (W) x .52" (D)	Monitoring excess noise levels	Monitoring work environment factors	W*orker level*	*Ttechnical measures*
56	Safety EYE technology – a system of safety cameras for three-dimensional surveillance of premises	[150] PILZ	 	Combination of smart sensors and effective controls. Innovative 3D technology and user-friendly software of the system allow for surveillance and control of comprehensive applications. The safe system of SafetyEYE cameras detects and notifies of any objects entering user-defined warning and safety zones. SafetyEYE determines whether there are people in zones exposed to hazardous movements (safety) or whether a case of trespassing a zone with higher safety level (protection) was detected.	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	Detecting the presence of worker in dangerous zones Monitoring of worker' activity	*Worker level*	*Ttechnical measures*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
57	FASyS project	[151,152]		Solutions included in the FASyS project apply to new methods of monitoring and managing occupational health and safety in factories. FASyS promotes active risk control, identification of most important risk factors and development of effective mechanisms of integrated risk detection. From the technological standpoint, FASyS provides a comprehensive platform for ubiquitous advanced functions of detecting, processing and more autonomous responses with regard to the reduction of risks and personnel information and training.	Monitoring and managing worker' safety in servicing, processing and assembly plants	Monitoring and managing worker' safety in servicing, processing and assembly plants	*Management level*	*Technical measures* *Organisational measures*
58	Project Virtual Factory Framework	[153] See also: [154-158]		The VFF project offers an innovative approach to the implementation of tools supporting design and simulating main activities and systems in factories, providing planning aid, supporting decisions, evaluation and validation possibilities.	Design and simulations Supporting managers in the evaluation of processes and validation of activities Supporting decisions	Information support Supporting decisions 3D modelling	*Management level*	*Ttechnical measures*
59	ActiPret project	[159, 160,161]		Tools developed within the framework of the ActiPret project allow for the observation of specialists performing complicated tasks, such as machine repairs and maintenance works. Their activities are interpreted in the form of 3D scenes, which can be watched at any time and place and by many users taking advantage of the Augmented Reality technology.	Worker support Training	Worker support Training	*Worker level*	*Oorganisational measures*
60	Project ROBO-PARTNER	[162]		The project included the development of: Multimodal interfaces of safe cooperation between a robot and a worker Human-centred interface for robot programming Mobile robots for applications in logistics Safety systems in worker-robot interactions	Monitoring robot parameters Examining human-robot interactions Adaptation to changing conditions	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Ttechnical measures*

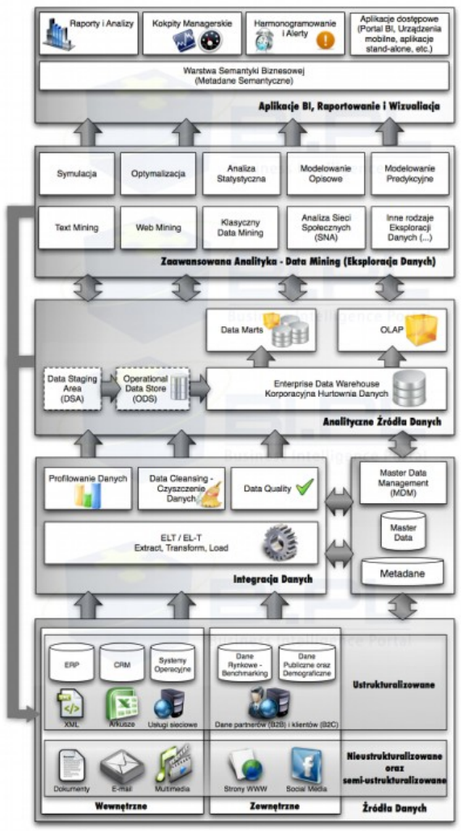
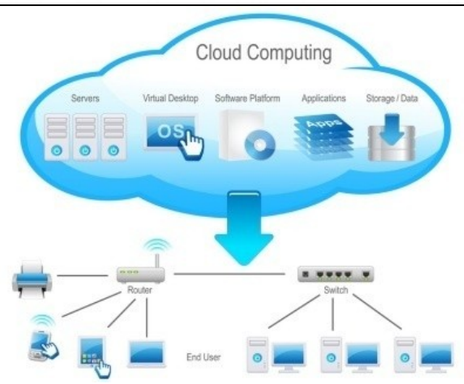
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
61	ROSETTA project Knowledge integration framework so that robots in a production line can share information	[163] See also: [164-166]		The project is aimed at developing technologies facilitating the use and integration of industrial robots in assembly lines. Automation. Industrial robots require the integration of robots and humans at assembly lines in order to achieve the highest possible flexibility in exploiting the advantages of humans and robots.	Monitoring robot parameters Examining human-robot interactions Adaptation to changing conditions	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Ttechnical measures*
62	LIAA project: Lean Intelligent Assembly Automation	[167,168]		The project provided a framework for the cooperation of people and robots during assembly works. LIAA framework was not developed from a theoretical standpoint, but taking advantage of extensive experiences of the partners, acquired during previously implemented projects. Solutions were created for five cases of real applications in five different industrial assembly areas.	Monitoring robot parameters Examining human-robot interactions Adaptation to changing conditions	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*
63	System for dynamic monitoring of robot working areas	[169] Carnegie Mellon University Robotics Institute		A solution ensuring real-time safety for worker located near robots. It took advantage of data from 3D imaging sensors. The algorithm dynamically updates risk zones according to the location of robots and safety zones according to the worker's position. If a likelihood of a collision is forecast, robots are put to a standstill.	Dynamic monitoring of robot working areas	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*
64	Intelligent Interference Check	[170] FANUC		Intelligent Interference Check ensures cooperation between the robot and other robots and coordination of operation of the robot and its equipment in a complex environment. When the distance between a robot and a fixture decreases, the robot reduces its speed so that it can stop at a suitable distance and avoid collision. Critical distances are defined using coefficients characteristic for each robot type, e.g. the speed slope factor, model size offset, max margin and approach stop rate. Robots can share the designated space using I/O signals for communication. Only one robot can work in the critical zone at a given moment.	Dynamic monitoring of robot working areas	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*

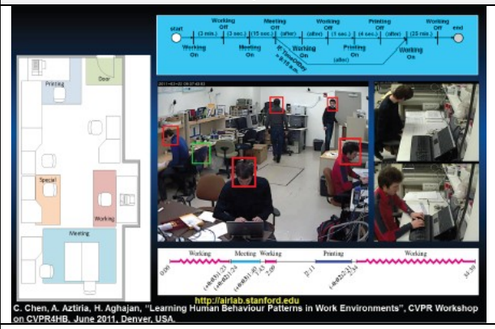
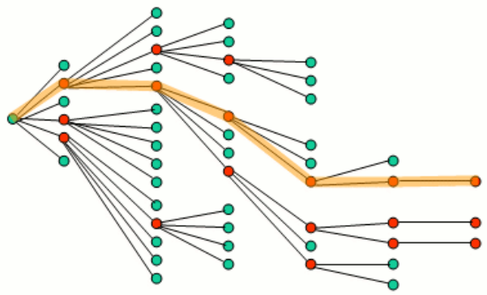
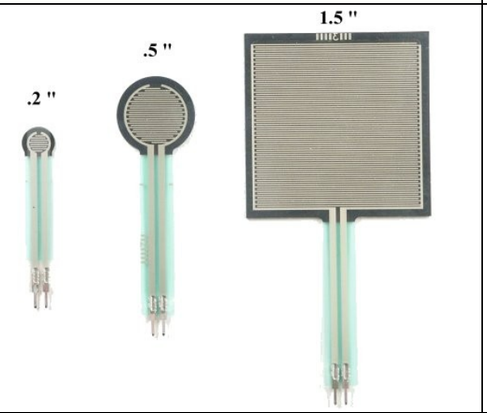
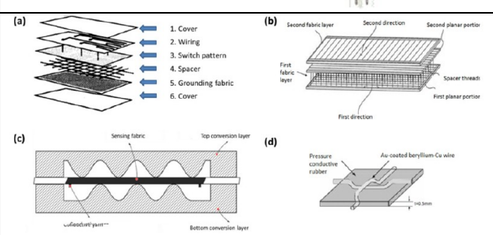
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
65	Dual Check Safety	[170] FANUC	 	Dual Check Safety – provides control over the robot's location, robot's speed and the tool's position. Dynamic activation / deactivation of of robot working areas is performed.	Dynamic monitoring of robot working areas	Monitoring machinery parameters and adaptation to changing conditions 3D modelling	*Machinery level*	*Technical measures*
66	Augmented Reality technology	[171] See also: [172-176]		Augmented Reality is a system combining the real world with a computer-generated environment. It usually makes use of 3D graphics generated in real time, imposed upon a camera image. There are also applications which only support sound.	Information support for worker Training	Information support for worker Training	*Worker level*	*Technical measures*
67	SHORE technology Object and face recognition Emotion recognition	[177,178] Fraunhofer IIS		A technology which makes use of a database of suitably classified faces (more than 10,000), which enables the identification of emotions and recognising objects and faces.	Driver support Recognising pain in patients Market surveys, e.g. impact of advertisements on their viewers Monitoring the level of fatigue Behavioural analysis	Information support Supporting decisions	*Management level*	*Technical measures*

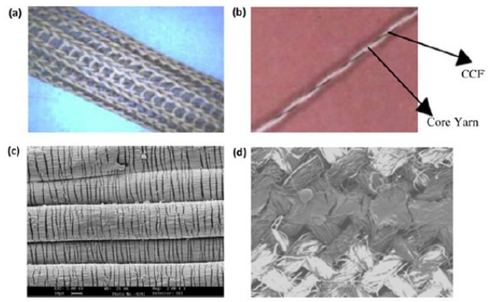
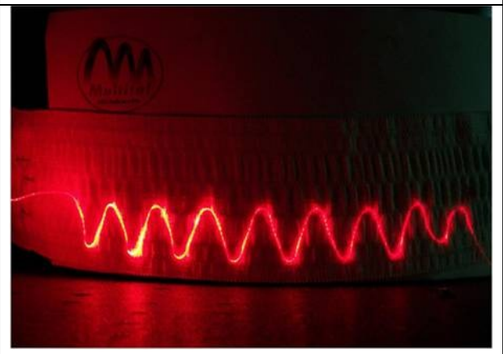
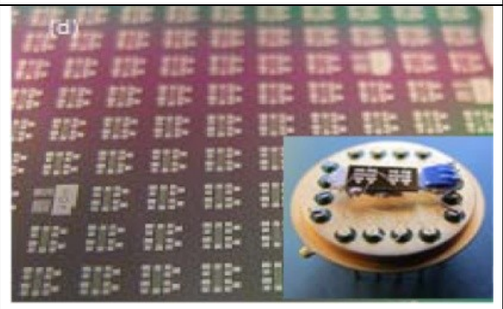
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
68	Saphari project: New variable impedance arms for enhanced safety	[179] See also: [180-194]		The SAPHARI project presents a radical paradigm shift in the development of robots by placing the human in the centre. Tests are carried out concerning human-robot cooperation and robot's responses to human activities based on decisions following from sensor signals and knowledge.	Monitoring robot parameters Examining human-robot interactions Adaptation to changing conditions	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*
69	AUTORECON project	[195] See also: [196-203]		According to the AUTORECON project, the factory of the future shall comprise the following technologies: Reconfigurable tools which allow for autonomous, flexible assembly of equipment to ensure easy adjustment of the production process to market changes. Smart monitoring and control systems enhancing performance and ensuring high level of reconfigurability of production processes. Integration of communication architecture to facilitate the integration and creation of networks using control systems based on web services. The architecture shall cover all communication and information exchange mechanisms, which provide for a simple connection of new components/robots, enabling their automatic configuration and operation and robot-robot cooperation.	Design and simulations of reconfigurable tools Design of smart control and communication monitoring systems Monitoring machine parameters Adjusting machine parameters	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*
70	X-act project	[204]		The X-act project is aimed at using advanced robotised systems in cooperation between European manufacturing and assembly plants. Research within the framework of X-act project focuses on the use of double robot arms in a production environment. The X-act project examines the human-robot interactions in the following directions: a) "Very intuitive interfaces for human and robot cooperation" in order to enable the cooperation between humans and robots during assembly tasks. b) developing a "Fenceless human robot supervision system" in order to provide the measures to detect/monitor human presence and suitably adapt robots' behaviours.	Monitoring robot parameters Examining human-robot interactions Adaptation to changing conditions	Monitoring machinery parameters and adaptation to changing conditions	*Machinery level*	*Technical measures*

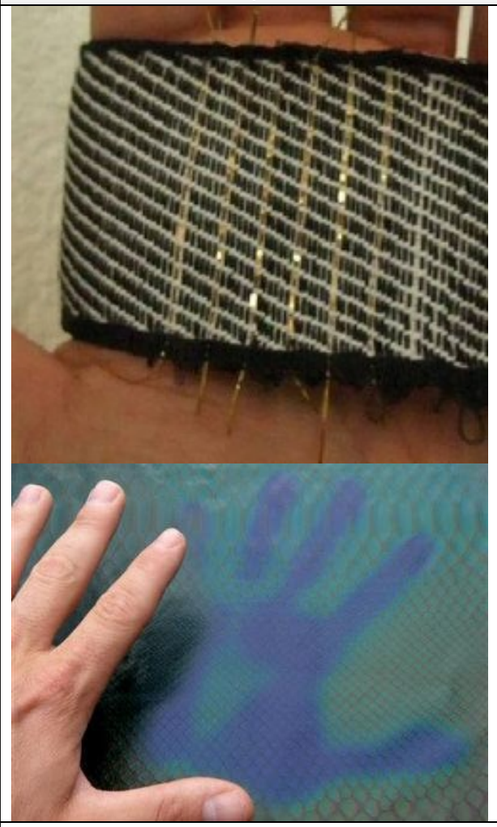
Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
71	Copernico project	[205] See also: [206-221]		Copernico is a free online tool used to analyse the current activities of a company and introduce performance enhancements. The database includes a wide range of factory types, from small and medium enterprises to global corporations.	Classification of production systems Diagnosis and improvement of production systems Modelling the structure, simulations and virtual prototypes of factories Developing strategies for the future	Information support Supporting decisions	*Management level*	*Technical measures*
72	BMS – Building Management System technology	[222]		Building Management System or BMS system automation is a management system for automatic building control systems, especially in smart buildings. The objective of BMS is the integration of all building systems. The building automation system integrates all systems in a single entity, which allows for cost-efficient and effective management of the facility from one place. BMS controls the operating parameters of individual devices and informs of problems and failures. Usually, the system features graphical interface, which can be used to review operating parameters and change settings in a clear way.	Communication Automatic building systems control and management	Information support Supporting decisions Communication 3D modelling	*Management level*	*Technical measures*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
73	SCADA – Supervisory Control And Data Acquisition technology	[223]	 	SCADA (Supervisory Control And Data Acquisition) refers to a system supervising a technological or production process. Main functions of this system include collecting current data (measurements), their visualisation, controlling the process, alarming and archiving data. The term SCADA usually refers to a master computer system with control over PLCs and other equipment. Generally, the PLCs are directly connected to executive devices (valves, pumps etc.) and measurement instruments (temperature, level sensors etc.) and collect current data from the facility as well as execute automatic control and adjustment algorithms. Via PLCs, data are transferred to the computer system where they are stored and converted into a more user-friendly format. The system operators preset general process parameters or run the process manually.	Production process supervision Visualisation	Information support Supporting decisions 3D modelling	*Management level*	*Technical measures*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
74	Business Intelligence tool	[224]		Business Intelligence is a tool for managers and experts who work on analyses and strategies. Business Activity Monitoring (BAM) solutions are intended for "line" managers who require information on the current state of processes. These solutions enable the processing of incoming data on a current basis. Presentation techniques are selected to match user's needs. In order to avoid browsing through a maze of numbers, the visualisation of the current state is provided in the form of images. The management dashboard is an attractive means of presenting results – it provides the visualisation of data and reports in a form resembling control panels.	Production process supervision Visualisation	Information support Supporting decisions 3D modelling	*Management level*	*Technical measures*
75	Model cloud computing	[225,226]		The principle of operation of this solution consists in transferring the entire load of IT (data, software or computing capacity) service provision to the server and providing constant access via client computers. Thus, the safety of these data becomes independent of the fortunes of client computers and the processing speed follows from the server's computing capacity. It is enough to log in from any computer with internet access to start making use of the benefits offered by cloud computing. The "cloud" concept is not unambiguous. In the broad sense, cloud processing applies to everything that is processed beyond the firewall, including conventional outsourcing.	Data storage and processing	Communication Information support Supporting decisions	*Management level* *Machinery level* *Worker level*	*Technical measures*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
76	Project Ambient Intelligence Research Lab	[227] Stanford University		Research project aimed at developing Ambient Intelligence techniques and applications in smart homes and offices.	Data exchange between the physical and digital world Service customisation Examination and modelling of user behaviour Examination and modelling of smart building systems User acceptance surveys	Information support Supporting decisions	*Management level*	*Technical measures*
77	Control algorithms and algorithms facilitating adaptation to changing conditions (fuzzy logic, neural networks, genetic algorithms, fuzzy systems etc.).	[228] See also: [229-237]		Mathematical structures in the form of software or hardware models, performing computations or signal processing, performing certain basic operations on their inputs.	Data processing	Information support Supporting decisions	*Management level* *Machinery level*	*Technical measures*
78	Pressure and force sensors	[238] See also: [239-248]		Capacitive sensors are mostly designed to measure pressure changes and to be used in applications such as touch panels. Solutions using modified electronics are also known in textile applications (e.g. conventional capacitors stuck or sewn onto a fabric and soldered to other electronic circuits or connection wires) and internally modified materials (e.g. capacitors made of fabrics made of conductive materials or textiles coated with conductive paint forming capacitor's electrodes and synthetic foam or soft polymer dielectric). The common feature of these solutions is the dielectric element separating the two electrodes. These solutions can be used as single sensors or as a matrix of sensors, with capacity measured in rows and columns of the matrix and collected by multiplexers. A separate group is formed by contact switches, which use the mechanism of measuring human body volume. Depending on the operational range and the intended application, capacitive sensors have downsides, such as creep, low resistance, signal drift and hysteresis. The impact of humidity and temperature is also significant.	Measurement of pressure changes Communication – touch panels	Communication Monitoring of worker' activity	*Management level* *Machinery level* *Worker level*	*Technical measures*
79	Resistance sensors	[249] See also: [250-255]		The relationship between pressure and electrical resistance is another principle used in the construction of pressure sensors. This type of structures can be made at all textile structure levels, e.g. yarn, fibre or coatings. The pressure of crossing yarns or conductive fibres on the matrix results in a change in electrical resistance. The position and pressure exerted on the fabric can be identified in places of resistance changes – this is how membranes capable of measuring the exerted pressure are made. Electrical resistance can be quantified by measuring resistance changes, conductivity or resistance. Resistance sensors in the form of coatings, which generate electrical signals by touching, have a different structure.	Measuring resistance changes, conductivity or resistance.	Communication Monitoring machinery parameters Monitoring work environment factors Monitoring health parameters	*Management level* *Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
80	Strain gauges	[256] See also: [257-279]		Textiles with strain gauges can be made at all textile structure levels, e.g. yarn, fibre or coatings. Such structures are vulnerable to mechanical deformations. Different topologies exist: interweaving strain gauge fibres or textile coating. Metal fibres, conductive threads and carbon fibres are used in the structure of textiles whose stretching causes resistance changes. These textiles can be transformed into "smart fabrics" by using piezoresistive, piezoelectric or piezocapacitive coatings, usually in the form of polymers due to their elastic properties. Coatings are modified from the outside or internally (e.g. conductive filler) and are sensitive to elongation and pressure changes, as well as other mechanical stimuli. Such structures are used in stretching materials, such as fibres, yarns and fabrics. Sensors in the form of coatings and piezoelectric elements generate voltage differences in response to many different physical stimuli, such as pressure, compression, tension or torsion. They can also be used for sound detection. They are made in many forms, such as coaxial cables, films and paints which can be directly connected, interwoven or applied onto fabrics. Solutions such as films embedded in garments in order to monitor heartbeat rhythm are also known. Accelerometers (force sensors) are also made using those structures. Touch applications of the sensors and position sensors are built on the basis of the piezoelectric resonance phenomenon. Changes in input parameters of the piezoelectric material in contact with the human body were also researched.	Measurement of mechanical deformations	Monitoring of worker' activity	*Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*
81	Optical sensors	[280] See also: [281-289]		Optoelectrical sensors work by sending a beam of light rays between a transmitter and a receiver. Measurements are taken of absorption and light transmission changes resulting from the changed geometry of the fibre's cross-section, refractive index of coating materials of the fibre optics, changes in wave spectrum and other properties. They are implemented in textiles by interweaving or using other types of bonds with fibres. Plastic and polymer optical sensors are introduced to fabrics and applied to detect deformations, measure temperature, humidity and pressure and detect the presence of organic and inorganic compounds. Structures made of optical fibres or coated, which temporarily change their colour in response to external stimuli such as light (photochromic), temperature (thermochromic), electricity (electrochromic), pH value (halochromic) and pressure (piezochromic), are also known. Electroluminescent fabrics are made using coatings made of electroluminescent polymers.	Deformation measurement Pressure measurement Measurement of organic and inorganic compounds	Monitoring machinery parameters Monitoring work environment factors Monitoring health parameters	*Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*
82	Detectors of chemical substances and gases	[290] See also: [291-299]		In textronic structures, miniature sensors detecting chemical substances and gases are attached (sewn or glued) to the fabric substrate or applied in the form of chemically sensitive coatings on textiles. For example, H2 and CO gases can be detected using conductive polymers with metallic inclusions. Toxic gas sensors can be made by embedding thin polypyrrole or polyaniline layers on PET (ethylene terephthalate) or nylon, which are then combined with the fabric. A change of resistivity can be observed when such structures are exposed to ammonia (NH3) or nitrogen dioxide (NO2). Electrically conductive polymer (PEDOT) is manufactured in the VDP technology and then used in structures for ammonia detection. PEDOT matrices can be used for monitoring nitrogen monoxide (NO) concentrations. Ethanol and ozone detection can be achieved by using coated polypyrroles. An optical fibre coated with PEDOT changes light absorption when exposed to HCl and NH4OH. Carbon nanotubes show the sensitivity of many analytes, including albumin – blood protein. Single nanotubes can discriminate between volatile compounds such as ammonium hydroxide, ethanol, pyridine and triethylamine.	Measurement of resistivity changes Measurement of light absorption changes	Monitoring work environment factors Monitoring health parameters	*Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*

Item	Name of the solution, technology / project	Source	Photo / Diagram	Description: principle of operation of the measure (e.g. phenomena and processes underlying the measure's operating principle, technologies, algorithms, etc.)	Functions of the measure	Functions in the occupational health and safety system	Position in the risk management process	Position in the prevention hierarchy
1	2	3	4	5	6	7	8	9
83	Sensors for temperature and humidity measurements	[256] See also: [257-277]		Humidity sensors can be broken down into two categories: resistive (reacting to moisture by changing electrical conductivity) and capacitive (reacting to water vapour by changing the dielectric constant). Tests have demonstrated that most of the fabrics coated with polymer humidity sensors work correctly in room temperature. The structures of temperature sensors are manufactured on flexible substrates, which makes their integration with the textile structure much easier. Resistance temperature detectors (RTDs) feature platinum and nichromium (NiCr) and associated materials. The BRT temperature detector was made of gold on a flexible substrate and its resistance changes linearly with temperature. Most conductive polymers and natural carbon-based polymers are characterised by their dependence on temperature, e.g. PEDOT-PSS fibres. Optical-fibre-based sensors and temperature sensitive paints are also used in those structures.	Measurement of changes in electrical conductivity Change of dielectric constant Measurement of resistance changes Measurement of light absorption changes	Monitoring work environment factors Monitoring health parameters	*Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*
84	Shape memory sensors	[300, 301,302]		Textiles with shape memory consist of shape memory alloys or shape memory polymers. However, shape memory polymers offer larger deformation ranges and have different types, characterised by various mechanical properties. Their smaller weight and price, as well as non-toxicity, also play an important role. Temperature and position sensors or failure sensors provide examples of the implementation of shape memory sensors in textiles. Shape memory properties depend heavily on the thermomechanical treatment of materials and the interaction between materials in the textile structure. Such structures can perform the function of self-regulating systems, responding to environmental changes.	Self-regulating systems – responding to environmental changes	Monitoring work environment factors Monitoring health parameters	*Machinery level* *Worker level*	*Technical measures* *Personal protective equipment (PPE)*