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Benchmarking of tools for User eXperience analysis in Industry 4.0

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Abstract

Industry 4.0 paradigm is based on systems communication and cooperation with each other and with humans in real time to improve process performances in terms of productivity, security, energy efficiency, and cost. Although industrial processes are more and more automated, human performance is still the main responsible for product quality and factory productivity. In this context, understanding how workers interact with production systems and how they experience the factory environment is fundamental to properly model the human interaction and optimize the processes. This research investigates the available technologies to monitor the user experience (UX) and defines a set of tools to be applied in the Industry 4.0 scenario to assure the workers' wellbeing, safety and satisfaction and improve the overall factory performance.

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Keywords: User experience; Human Factors; Industry 4.0, Production system design, Human Interaction.

1. Introduction

Industry 4.0 indicates the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems (CPS), the Internet of Things (IoT) and cloud computing to create what has been called a "smart factory". Within modular structured smart factories, CPS monitor physical processes and create a virtual copy of the physical world to make decentralized decisions on the basis of the collected data and the created knowledge [1]. Over the IoT, such cyber-physical entities can communicate and cooperate with each other and with

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humans in real time, and both internal and cross-organizational services are offered and used by the participants of the value chain. In the context of Industry 4.0, manufacturing will become smart and adaptive thanks to collaborative and flexible systems able to solve the problems arising during the process and execute the best actions [2]. Such scenario offers new and interesting development for the modern companies but contemporarily creates a greater system complexity, with an enhanced human-machine interaction that requires highly variable and changing tasks as well as new demands [3]. Indeed, workers will be faced with a large variety of jobs ranging from machine control to process monitoring, until verification of production strategies. As a result, although industrial processes are more and more automated, human performance is still the main responsible for product quality and factory productivity, and too high human workload risks to be the real bottleneck of the smart factory [4]. Only reducing human errors and improving the workers' capability to make strategic decisions and to be flexible problem-solvers can guarantee a higher system efficiency and factory productivity, with less cost and less resources' consumption.

The Industry 4.0 framework allows the physical systems to be digitalized by Internet of Things in order to communicate and being interoperable each other. Thanks to a virtual copy of the physical world through sensor data, information can be contextualized to have self-adapting systems able to intelligently adjust the production patterns for difference scopes [5]. Machines, devices, until the entire production systems can be one if those "things", virtualized and managed by the Industry 4.0 approach. However, factories are not only made up of machines but also of human beings (i.e., workers) cooperating with the machines and each other in various ways: executing tasks, controlling the process, loading or unloading the machines, interacting the machine interfaces, etc. So in the smart factory also people could be seen as "things" to be monitored and connected with each another and with machines. Indeed, although the increasing level of automation of production lines, humans still continue to have a central role in factories and are the main responsible for successful factory productivity and high product quality [6]. According to the Industry 4.0 paradigm, the factory system could support workers' in task execution, data interpretation, and context-aware making decision to carry out their job more safely and more comfortably, which allow reducing time and improving quality. Furthermore, in the last few years new methods of investigation of humans' behaviours and feeling have been developed based on physical and physiological measurement, to guarantee a more objective way of investigation. In general, monitoring tools like heart rate (HR), electrocardiogram (ECG), electroencephalogram (EEG), electro-dermal activity (EDA) and others are used mostly in medical research to investigate diseases or other disorders [7]. Nowadays, thanks to the miniaturization and cost reduction of most of those technologies, their adoption is growing also in design and engineering contexts for behavioural analysis and stress monitoring.

This paper provides an extensive analysis of existing technologies to monitor workers' behaviours, actions and feelings in industrial applications in order to enhance system productivity. In particular, the paper focuses on the analysis of the so-called user experience (UX) that refers to the analysis of humans' behaviours and perceived experiences while interacting with machines, systems and products during their job. Traditionally, the workload and the level of stress of workers are measured by direct observation, users' interviews and questionnaires. However, such methods provide a late assessment of the working conditions and are strongly influenced by the subjectivity of the involved users. Late assessment allows problems' evaluation, but does not support a human-centred integrated design of both product and processes, to substantially improve the process performance. The aim of this paper is to inquire how human monitoring tools can be used to evaluate physical and mental workload of workers and how to correlate such data with the design of the working environment in order to achieve better working conditions and more efficient workflows. In particular, such tools could be adopted for real-time monitoring and smart product-process re-design to improve the factory performance. The main findings of the research are:

1) a set of human factors' monitoring tools for UX analysis,
2) an experimental set-up for UX analysis to be easily adopted in in smart factories, and
3) a preliminary industrial case study, where the above-mentioned set-up is adopted.

2. The research background

The concept of human-centred manufacturing is not new but raised in 1990s [8]: it places human beings with their skills, behaviours, creativity and potentiality, at the centre of the activities carried out by technological systems, and focuses on how humans interact with technology, questioning how and why technology may be of service in supporting human work. However, in early 1990s technologies were not mature enough to easily include workers