End-User Development in Industry 4.0: Challenges and Opportunities

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Abstract. This position paper aims to discuss challenges and opportunities related to human-computer interaction technologies for Industry 4.0 and to explore the role that end-user development can play in new industrial scenarios. The paper highlights the gap between what Industry 4.0 and related enabling technologies promise and how the Operator 4.0 will be called on to change his/her work practice. End-user development and meta-design are here proposed as suitable methods to fill this gap and improve operators' quality of work.

Keywords: Industry 4.0 · End-user development · Meta-design

1 Introduction

The fourth industrial revolution, also called Industry 4.0, is transforming industrial manufacturing with the introduction of cyber-physical systems, industrial internet, collaborative robots, and advanced human-computer interaction technologies [14]. Collaborative robots will work in direct cooperation with humans, by also requiring to be (re-)programmed easily to cope with quick changes in production batches; and smart and mobile technologies, including virtual reality (VR), augmented reality (AR) and wearable devices, will be used to perform daily work in novel and more efficient ways. However, if not properly managed, this scenario risks to have a negative impact on operators' quality of life, also considering that demography is changing, shortage of skilled workforce is observed in most of European states [5], and health-related problems may be brought about by new technologies. Therefore, designing and evaluating novel interaction modalities between operators and machines to support the different facets of the Operator 4.0 [13] will become fundamental in the next years.

End-user development (EUD) [12] might represent a possible answer to shape such interaction modalities and help operators tailor tools and workplaces to their needs and preferences. The EUD definition has been recently refined in [2] to comprehend the shaping, on behalf of end users, of both hardware and software technologies in order to accommodate them to different uses and preferences. Most of the enabling technologies foreseen by Industry 4.0 involve novel interaction devices that should be integrated in daily work without worsening the quality of work, in terms of security, mental effort,

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visual difficulty, physical fatigue, discomfort, disorientation, and so on. Studying suitable EUD methods and techniques for the Industry 4.0 and framing the intervention through meta-design [6] is a challenge to address in the next years.

2 The Operator in the Industry 4.0 Era

Technologies fostered in the frame of Industry 4.0 aim at providing industrial manufactures with several opportunities for increasing efficiency, flexibility and production capability. Promoters of Industry 4.0 claim that human operators will be better supported to prevent errors, recognize machine failures, change production, perform maintenance activities, and avoid repetitive tasks. Work environment themselves promise to change providing operators with greater autonomy and problem-solving capability, enriching the quality of work with an engaging user experience, fostering novel ways for collaboration and knowledge sharing, and ensuring security of the workplace.

Romero and colleagues [13] identified and discussed eight types of operator in Industry 4.0, which reflect the above changes in the factories:

1. The *super-strength operator*, that is a worker empowered by a human-robotic exoskeleton that increases strength and endurance.
2. The *augmented operator*, who uses augmented reality devices to transfer digital information in the physical world in a non-intrusive way.
3. The *virtual operator*, who uses an immersive multimodal environment for simulating interventions or training in some specific tasks.
4. The *healthy operator*, that is a worker endowed with devices (e.g., wearable trackers) for monitoring physical and cognitive workload and scheduling work-shifts accordingly.
5. The *smarter operator*, who interacts with intelligent personal assistants and Internet of Things (IoT) solutions to receive reminders and instructions.
6. The *collaborative operator*, that is a worker operating in direct cooperation with a robot that helps him/her perform repetitive and non-ergonomic tasks.
7. The *social operator*, who uses mobile devices and social networks to connect with other operators and smart things to access, share and manage knowledge.
8. The *analytical operator*, who analyzes data collected in the smart factory and processed by machine learning algorithms to monitor factory performance and predict relevant events.

In this scenario, human operators will be called on to do fewer manual activities in favor of problem-solving tasks that require information and knowledge management [9]; complexity thus may increase, but operators might not have the background and competences necessary to deal with such complexity [10]. The engaging user experience offered by AR, VR or wearable devices might require more flexibility and adaptability on behalf of end users, who may also be called on to evolve rapidly as the work environment evolves. Operators' mental model of tasks and machines will need to be modified; advanced technologies will mediate the interaction with traditional machines and provide huge amount of data to be processed for decision making.

In order to keep the human in the loop and really support human workers by improving their quality of life, enabling technologies for Industry 4.0 must be properly deployed and managed.

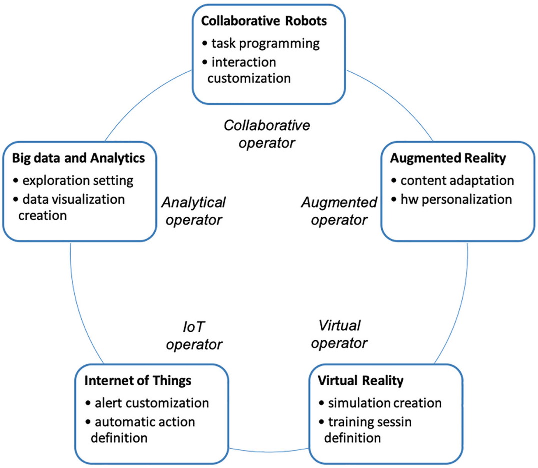

Fig. 1. EUD for the operator 4.0.

3 Filling the Gap with EUD and Meta-Design

We claim that the integration of EUD methods and techniques with the above enabling technologies might help human workers evolve more smoothly into the different types of Operator 4.0. For instance, Beschi et al. [4] propose a new approach to collaborative robot programming, by providing users with a natural interaction to define simple tasks and allowing them to gradually learn new possibilities for complex task creation. Several initiatives in the cultural heritage field show how AR solutions could become sustainable in the long term only if domain experts can be supported with EUD environments that allow customizing contents and presentation [8]; at the same time, hardware technologies employed in AR solutions, such as head mounted displays and smart glasses, might need to be easily tailored to the operators' preferences and physiology in order to limit cognitive efforts and fatigue [11]. Simulations and training sessions to be carried out with the help of VR might require to be created by end users not knowledgeable in computer programming to support context-dependent practices and specific operators' characteristics. Design environments for IoT behavior control and management could be necessary as well; they might be inspired to those ones proposed for smart environments, which are usually based on the rule-based paradigm that proved intuitive for the majority of people [1, 7]. Finally, the definition of data visualizations customized to users' interests, preferences and skills might need to be supported in the context of big data and visual analytics.

Figure 1 synthesizes the opportunities offered by EUD to support the different types of operator. The *super-strength operator* in [13] has been included in the *augmented* *operator*, by assuming exoskeletons as a form of augmentation that must be (physically) personalized to the user; whilst, the *smarter operator*, *healthy operator* and *social operator* have been comprised in the *IoT operator*, which is able, through EUD, to manage the entire IoT ecosystem, as conceived in [3].

In summary, enabling technologies for Industry 4.0 should be tailored to the work context and type of operator by the users themselves; this means providing them with one or more EUD environments conceived within a meta-design framework, which not only focuses on enabling technologies, but also and above all can sustain the cultural transformation [6] necessary to address the future complexity of work and workplaces.

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