Cognitive Human Factors in the Artificial Intelligence of Things

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***Abstract*—Internet of Things (IoT) systems are increasingly becoming complex. Heterogeneity in terms of hardware, software, computing capacity and connectivity is a source of complexity. The conversion of IoT systems into cyber-physical systems, including devices that are able not only to collect but also to process and take decisions, in real-time is a second source of complexity. Moreover, not only sensors should be considered, but also actuators, especially robots in the industry domain. In this context Artificial Intelligence (AI) technologies provide powerful capabilities to endow IoT devices with intelligent services, leading to the so-called Artificial Intelligence of Things (AIoT). In this context, the operator/user is in the middle of this complexity trying to understand the current situation and make effective real-time decisions. Hence, human factors, especially the cognitive ones, is a major issue to be addressed. New software development methods in the form of assistants and wizards are necessary to help operators/users to be context-aware and reduce their technical workload about coding or computer-oriented skills, focusing on the task/service at hands.**

***Index Terms*—human factors, artificial intelligence, internet of things**

I. Position Statement

The introduction of disruptive technologies in the workplace integrated through cyber-physical systems causes operators/workers/users to face new challenges. These are reflected in the increased demands of operator's capabilities physical, sensory, and cognitive skills. In this perspective, assistants are introduced as a possible solution, not as a tool but as a set of functions that amplify human capabilities, such as exoskeletons, collaborative robots for physical capabilities, or virtual and augmented reality for sensory capabilities.

The human is an indispensable resource into the workplace. Not only production lines and processes are changing, but also the role of the human is subject to significant changes and turns out to be crucial for developing productive systems [1]. One might think that people in the production hall will not be any more needed except for repairs and maintenance. Such theories of 'unmanned factories' have instead been discussed decades ago during the CIM (Computer-Integrated Manufacturing) era. In practice, instead, the factories will not be without humans. People will work or operate with sensors, robots, machines, cyber-physical systems and other humans [2]. The importance to emphasize the role of the human being as a critical driver for a better work performance has been pointed out by many visions and road maps about the future factory [3]. However, although their role is indisputable, humans can make mistakes that, no matter what their origin, have a direct influence on the cost of non-quality and delays. Some studies have demonstrated that human-caused non-quality is due to three main reasons: lack of appropriate guidelines, gaps in training, and the unavailability of documentation in production lines. As a result of the disruptive technologies the (human) operator must deal with different working situations, as a consequence of either changing work-places in the production lane, or changing production schemes and software products in the same work-place [4]. Operators must be aware of important elements in the situation and to interpret it correctly according to their task of interest. Being constantly aware of all these elements is a difficult task for the workers and may lead to a cognitive overload that must be reduced.

Although most standard situations can be handled by automation through cyber-physical systems (CPS) or Artificial Intelligence of Things (AITo), operators must monitor and tune the automated system to keep its functioning within specified bounds. Moreover, automated systems are not capable of dealing with unanticipated situations [2]; humans can learn from experience and thus compensate for incomplete knowledge. Humans can also adapt to different situations and prioritize different goals according to current demands. Thus, humans compensate for inevitable design shortcomings by learning and acting in flexible, context-dependent ways [5].

In addition, both the products and the production environment are becoming increasingly complex. In this context it is proposed to put emphasis on the principles of human centrality [6], as part of the disruptive transformations, with a paradigm shift of independent human and automated activities towards a human-automation symbiosis or *human cyber-physical system* (HCPS) [7], [8]. These systems are characterized by the cooperation of machines with humans in work systems and designed not to replace the abilities and skills of humans but rather to coexist with humans and help them to be more efficient and effective. In this symbiosis of human and machine team, research will seek the gain of both parties from a cognitive viewpoint.

The only automation perspective, however, is not enough to

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deal with the cognitive issue, an additional view is needed. A socio-technical system's perspective is presented in the cognitive systems engineering domain which is dedicated to the careful study of human/machine interaction as the meaningful behaviour of a unified system, introducing joint cognitive systems (JCS) [9], offering a principled approach to studying human work with complex technology.

A combined view from automation and JCS systems proposes the need to support the employee with available assisted technologies in order to cope with the increasing diversity of work tasks and the complexity of industrial production. A major aim is to increase and support existing capabilities of the worker and/or compensate shortages or deficits of the employee. There is currently a need for research on:

- Need for further case study applications of worker assistance systems.
- Missing methodology for the selection of appropriate worker assistance systems for specific user groups.
- Missing methodology for a structured evaluation of the suitability of worker assistance systems.

In this sense, focusing on the manufacturing domain, according to a study by the German Federal Ministry of Economics and Technology about Industry 4.0 this need is shown among the five areas in which Industry 4.0 solutions are developed [10],

- Decentralization and service orientation
- Self-organization / autonomy
- Networking and integration
- Assistance systems

Only for illustrative purposes, let us mention two examples of general approaches about new software development methods to be developed in the form of assistants and wizards to help operators/users to be context-aware and reduce their technical workload about coding or computer-oriented skills, focusing on the task/service at hands. The first exmample refers to the principles of human centrality developed in the form of the Operator 4.0 [6], [11], [12]. Assistants integrating ERP (Enterprise Resource Planning) /CRM (Customer Relationship Management) decisions with the operator in the workplace should help to a better understanding of the work in hands as well as changes in the production lane in the form of quality, time or task. The second example relates with the idea of 'no code robot programming' [13]. Current robotic technology in the form of cobots is affordable for small and medium enterprises (SMEs), however its adoption is being delayed mainly due to the associated engineering / coding skills needed to take profit of this kind of installations. Assistants and wizards should be developed to reduce their technical workload about coding. Learning by demonstration, semantic awareness and ontologies are areas to be explored.

In conclusion, the need of operator assistants from the perspectives of cognition and human-machine symbiosis through HCPS is the motivation for this position statement.

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