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Design and Research for Advanced Human Augmentation in the Industrial Work Context

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Abstract. Advanced human augmentation provides a human-centred perspective on technology design. It builds upon earlier technological concepts such as ubiquitous computing, wearable computing, augmented- virtual- and mixed realities, autonomous systems and ambient intelligence. This tutorial contemplates advanced human augmentation in the industrial work context, and considers the requirements for a future augmented Superworker and the prerequisites for their advanced augmentation. In this tutorial, it is anticipated that to support the design of new augmenting solutions current human-centred design practices should be reconsidered and enhanced in new directions.

Keywords. Advanced human augmentation, augmented human, Human-computer Interaction (HCI), Human-centred design (HCD), Core-Task Design (CTD)

Introduction

Advanced human augmentation suggests technologies that augment and enhance human actions, senses and work in new, yet unexplored ways by allowing humans to see, hear and feel the surrounding environment in new and enriched ways [1-3]. The aim is to utilize the existing and envisaged technologies for meaningful human-defined purposes in augmenting humans in appropriate ways. In international research, the topic has aroused a great deal of interest, as currently many powerful research institutions and companies (including MIT, Stanford University, Google Inc, Samsung Electronics Co. Ltd, the US Army etc.) are intensely investigating the potentials for the emerging field[2,3]. The technical interaction concepts are based, for example, on virtual, augmented and mixed reality (VR/AR/MR) solutions, wearable computing devices, smart materials, brain and skin interfaces and near-eye displays. The information provision for the augmented human utilizes e.g. activity and behaviour analysis, personalization, situation and context awareness, in addition to the latest agent communication and artificial intelligence techniques [1]. These technologies have the

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[2] http://www.marketsandmarkets.com/PressReleases/human-augmentation.asp.

[3] http://www.augmented-human.com

potential to enhance and augment human life to a great extent, but they also require new human-technology interaction solutions.

To make advanced human augmentation a reality, wearable and embedded technologies may be employed as mediators for augmenting human sensing and actions [3, 4]. Furthermore, direct brain-computer interfaces and autonomous technologies may allow the augmenting of human actions even more directly [5, 6]. The path is open even for organic extensions and stimulation of sensory axons in many different areas of life, as described e.g. in [7]. By advanced human augmentation, people may also be empowered with new cognitive abilities and direct connection to global information and services with technologies that serve as "external eyes and ears" for sensing the ubiquitous information [8, 9]. Consequently, human augmentation technologies can improve the quality of life for people with special needs, including the blind, the deaf, people with motor impairments, etc. Elderly people suffering from a deterioration of the senses, people with certain illnesses, and people injured in accidents may be helped with new solutions that replace or improve damaged senses [10]. Through these technologies, new possibilities for remote existence and new forms of human actions can also be achieved.

The research proposed in this tutorial aims to contribute to advanced human augmentation by defining a practice- and future-oriented design approach for its design and research. In essence, the research contributes to design science [11, 12] and three disciplines – design, Human-computer Interaction (HCI) and Augmented Human (AH) research. In particular, the tutorial aims to study the concept in the industrial work context; by focusing not only on the interaction tools, but also on the human practices. The hypothesis is that, in order to receive the full benefit of the emerging systems, both the tools and the work practices have to be re-considered. Thematic areas for advanced human augmentation can also be associated with the perception of information in the environment and artificial intelligence in systems that enhance human senses. Consequently, as the aim is to enhance human perception, it is assumed that the prevailing prototyping technologies may not be mature or advanced enough to facilitate appropriate user experience investigations. Therefore, the proposed systems should be demonstrated by design- and future-oriented research that will also take into account the ethical and societal perspectives of the emerging technologies.

1. New ways of working

Based on previous research on the work context [14-18], it is to be anticipated that new advanced human augmentation solutions will strongly influence industrial work tasks. According to MacDougall, many industrial jobs are anticipated to become knowledge-intensive and even new work roles are expected to emerge [19]. Future workers will monitor and supervise autonomous systems, which necessitates that the employees possess multifunctional skills and take more responsibility in the content of their work. Work tasks are shared flexibly between automation systems and the human workers.

In Figure 1 we illustrate our vision of the future Augmented Superworker. The figure exemplifies how the focus of the employee's wearable enhancements will shift from safety and security towards connectivity, comfort and efficient co-operation with intelligent automation. Future industrial work is expected to move towards a shared awareness with autonomous systems where location becomes inessential, because future work places are not limited to the company's premises, but co-operation takes

place between different facilities and people outside its premises. Accordingly, the content of the work moves from distributing the workload and observing the workers towards co-evolving a human-autonomous system partnership. From the workers' point of view these new ways of working indicate that future employees will need to trust their systems; they need to experience control over their tools and ownership of their work processes, and, primarily they require advanced and efficient tools for working in their new operational environments.

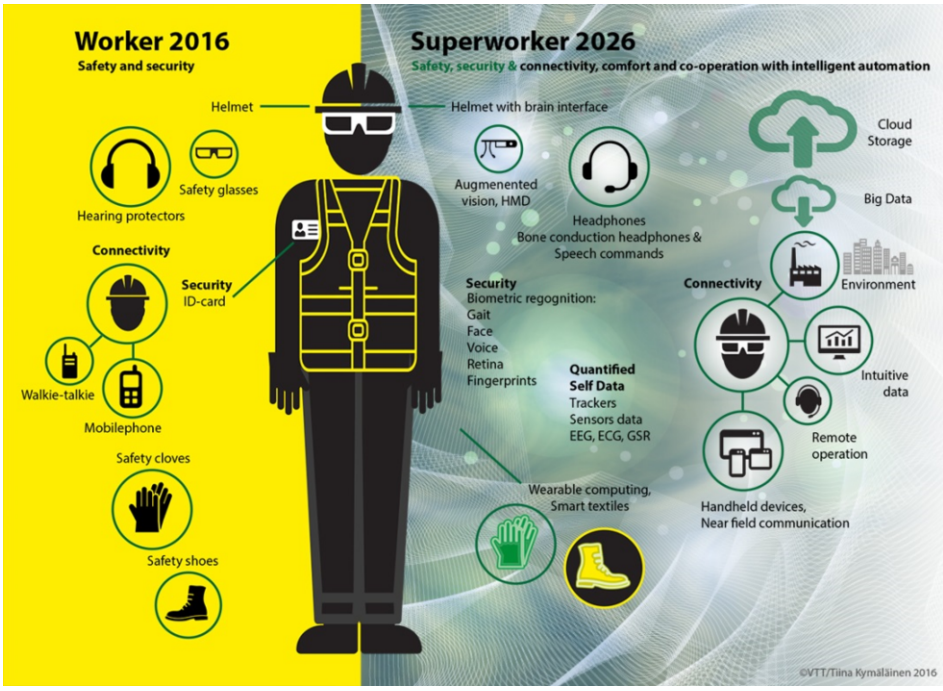

Figure 1. Vision of the future Superworker.

2. Advanced human augmentation process and practices

The tutorial will at first briefly introduce the multidisciplinary research that has previously deliberated on human factors, core-task design, participatory and human-centred design in the research and development of future industrial working environments. This research has related e.g. to process control and remote operation work in various work contexts: electrical and nuclear power plants, oil refineries, paper mills, crane operation, the maintenance of work machines and intelligent machine operation in forestry, mining and agriculture. This past work has already generated recent knowledge about the workers (e.g. remote, production and field operators) in these industrial domains, i.e. there is already a vast amount of information about, for instance, workers' professional background, core tasks and duties, work characteristics, tools and working environments. This information is important for defining the premises for advanced human augmentation; its critical tools, tasks and experiences.

The subsequent objectives for the tutorial are twofold:

1) To consider the suitability of the practice-theory approach to design and research for advanced human augmentation
2) To consider possible future-oriented prototypes and science fiction-inspired design solutions for the future Augmented Superworker.

It is anticipated, that for supporting the design of new advanced human augmentation solutions, current human-centred design (HCD) practices need to be enhanced in two directions. Firstly, the design of work practices and the design of tools need to be better interconnected. Secondly, HCD practices should take into account future-oriented design thinking in order to facilitate the design of future work practises parallel to the evolving technologies.

Regarding the integrated design of work practices and tools of a good quality, a holistic perspective and acknowledgement of the scale and richness of human capabilities is demanded. The tutorial suggests the design and development of advanced human augmentation in order to build upon recently proposed practice-theory-based design approach called Core-Task Design (CTD) [20]. The CTD methodology adopts "practice" as the key notion to define and to contextually understand the work. According to practice-theory approach, focusing on practices makes it possible to capture human activity in context-dependent manner. Practices are stable forms of embodied acting that are appropriated in societal connections as meaningful for the community. Thus, the practice-theory also assumes conceiving of activity from the organism-environment, i.e. a joint human-technology system perspective where practices are considered to be products of joint functioning of human actors, the physical and social environment and the tools used for reaching the actors' objectives. This joint form of activity is operationalized in CTD approach by introducing the concept of core task. Core task refers to *"the generic developing content of the work and expresses itself as joint functions emerging from the meeting of the human organism's resources with the possibilities and constraints of the environment for reaching certain global objectives of work activity"* [20], in p. 25. Core-task portrays the purpose, possibilities and constraints of activity [21]; an appropriate and developing work activity caters for the potential inherent in the core task. In the design of complex work systems and in particular, augmenting the human worker's capabilities to act as an equal part of the system, the core task may provide a comprehensive reference against which the activity can be analysed. Moreover, human conduct is equipped with certain resources for acting which in CTD are grouped into three classes: pragmatic resources, i.e. skills; epistemic resources, i.e. knowledge; and heuristic resources, i.e. collaboration including self-reflection. In consequence, development of advanced human augmentation may be directed to enhance and address all or some particular aspects of the human capabilities to be connected and act within the work system. In essence, the CTD approach introduces three main design functions, i.e. 1) understand-to-generalize, 2) foresee-the-promise, and 3) intervene-to-develop, so as to incorporate appropriate human understanding in the design.

The second, most future-oriented design function of CTD is dedicated to answering the question of how to see the promise of new solutions for future work. In the function, generalization of the present work may create a certain basis for analysing the future value through projecting the core content of the work to optional concepts of new work, i.e. in the case of the present tutorial new forms of human worker

augmentation in a work context. For instance, the "potential activity" emphasized in the foresee-the-future function may be investigated through the InnoLeap Process developed at VTT, which has been employed for many successful company design cases, e.g. for Rolls Royce [22]. The process is based on trend and user studies, work analysis, co-innovation, and reflective approaches including design and foresight methods. Future-oriented design will also rely on the science fiction prototyping (SFP) method that aims at iteratively designing research-based design artefacts, anticipate the long-term consequences of technologies and focus on their new understandings [23-25]. The suitability of such methods as design fiction [26], research through design (RtD) [27], reflective design [28], critical design [29], imagination workshops [30] and Diegetic Innovation Templating (DiT) [31] will be briefly contemplated in the tutorial.

When considering potential future-oriented concept prototypes and science fiction -inspired design solutions for the future Augmented Superworker, the aim is essentially to consider the new practices that enhance or augment the worker's actions, senses and cognition, and create a seamless technology environment for human interaction. The tutorial aims at practical design cases for a future Augmented Superworker, including their tools and the environment.

3. Concluding discussion

Industrial work is currently going under radical changes, because of digitalization and the employment of autonomous systems. The advanced human augmentation research presented in this tutorial supports the changes from the workers' perspective by providing ways in which not only tools but also work practices can be redesigned. This allows us to gain the full benefit of the new technologies both in terms of increased productivity and increased worker satisfaction.

Global human augmentation research is currently paying a lot of attention to newly developed technologies, and human factors research is mostly focused on the interactions rather than on the human practices that these technologies will facilitate. Thus, a future-oriented design approach that integrates the design of work practices and technical tools has potential for scientific breakthroughs in this field. The main objective of the tutorial is to deliberate a practise- and future-oriented advanced human augmentation design approach that aids us in judging, instructing and supporting the design processes, and facilitates developing the work practices and technical solutions in parallel. The design investigations for the design approach will start by considering the path from present to future and by prioritising key focus areas and emerging technologies. The design research identifies opportunities for advanced human augmentation concept development, and explores suitable design strategies that aid in constructing the systems in a clearly defined manner. Future-oriented research promotes anticipatory thinking and broadens the scope and opportunities for design research. Future-oriented design has the potential to study the emergent design requirements of the human-autonomous system partnership that come to the fore when intelligent applications take on some of the cognitive tasks previously performed by humans. Consequently, the hypothesis is that future-oriented design provides a general and holistic (yet practical) understanding of the human augmentation technologies currently under-construction. The future-oriented design process is expected to provide important, fundamental information for the field, since human-centred automation

approaches are currently important themes on a number of national and international research agendas.

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