INDUSTRIAL CHALLENGES IN HUMAN-CENTRED PRODUCTION

Dr. Wolfgang Unzeitig[1], Martin Wifling[1], Dr. Alexander Stocker[1], Manfred Rosenberger[1]

[1]VIRTUAL VEHICLE Research Center
Inffeldgasse 21/A, 8010 Graz, Austria

Abstract

On the way to future Smart Factories the role of people in production plants is becoming increasingly important too. Supporting production workers through providing them with action relevant data, information and knowledge via modern information technology has become a central topic of research. Against this background, a Horizon 2020 project has been launched exploring the future role of the production worker in Smart Factories. This paper outlines the four industry challenges of the FACTS4WORKER project, personalized augmented operators, worker-centric knowledge management systems, self-learning manufacturing workplaces and in-situ mobile learning in the production. These four challenges provide the required research framework for developing a smart factory solution consisting of technology building blocks which are combined in a smart way to empower the worker for flexible production.

Keywords: Smart Factory, human-centred production, production workers, flexible production

1. INTRODUCTION AND MOTIVATION

“Factories of the Future” is a commonly used wording on European level, whenever production related research is addressed. Several authors [2, 6, 8, 11, 13] assign high potential to combine the factories with a networked information and communication technology (ICT) that collects processes and presents large amounts of data. While “Smart Factories” are able to autonomously keep track of inventory, machine parameters, product quality and workforce activities, the worker will play a central role within future forms of production, especially in small and medium enterprises.

Taking the current speed in user-centric technology development and adoption on the private level into account, we stand at the edge of achieving really worker-centric smart factories. It seems to be the perfect time for a human-centered revolution in factories, as both technological (Social Software, Semantic Technologies, User Profiling, Big Data, ..) and social enablers (user generated content, users add value, network effects per default, harnessing the collective intelligence, ...) have successfully emerged. Today, a technology-affine young generation acts both as producer and consumer of information and knowledge on the Web, and is capable of bringing creative and networked-thinking into production environments, too. At the same time many 50+ factory workers of today are also beneficiaries of powerful human-centred technology, which they have already adopted in their private context.

In the project “FACTorieS for WORKERS” (FACTS4WORKERS) funded by the European Commission in the Call Factory of the Future (H2020-FoF-2014) human workforce in factories on all levels from shop floor to management should be strengthened in their flexibility. The project aims to increase problem-solving and innovation skills, cognitive job satisfaction and worker productivity, finally attracting more young talents to factory work. The human resource is the most skilled, flexible and productive asset of any production system. Hence, FACTS4WORKERS' idea is to support shop floor workers intelligently by all means modern ICT can offer. The research work focuses on developing a seamless and flexible IT-infrastructure with worker-centric and data-driven technology building blocks considering usability, user experience and technology acceptance. Advancement will be gained through integrating several of these building blocks into a flexible smart factory infrastructure, focusing on workers’ needs, expectations and requirements, and being supported by organizational measures and change management.

In the last decade, the bulk of information and communication technology based revolutions stemmed from the World Wide Web in the private domain:

- The user-focused Web 2.0 has empowered humans to become producers with Social Software, allowing anyone to easily acquire create, share, and modify content in an intuitive way. Simplicity and user-centricity have become the dominating design principles of successful software. [10, 15]
- The pervasion of mobile devices including smart glasses and watches has even more contributed to establishing a Social Web per default equipped with human-features and filled with content co-created by humans of all age with software designed for a joy of use.
- The Semantic Web [3] provides data-frameworks and semantic technologies to express and process information in machine-readable form. In Berners-Lee's vision the Web is not limited to human to human interaction anymore, but also machines will participate and assist. Intelligent agents provide users with information from linked data. The Semantic Web in some ways acts like a global database.
- Volume, velocity, and variety of data are continuously increasing: The term Big Data [12] points to the huge potential of deriving valuable insights from data to transform how humans live, work, and think. Today's data experts can analyze an entire dataset instead of seeking statistically representative portions, tolerate more errors in the data, as its size has increased, and care less about causation, and more about correlation, answering questions with brute force, instead of generating and testing only hypotheses.

Developments from Web 2.0 and Semantic Web have already been taken-up in office environments to facilitate knowledge management [3, 9, 14]. Social Software has enabled new ways of knowledge sharing, social interaction, and collaboration at the workplace, while semantic technologies can be used to better target information to humans and processes. Modern ICT has shown a high potential to empower knowledge workers [1]. Likewise, many efforts have been conducted to optimize 'manual work', ranging from the contributions of Taylor and Ford to current phenomena including Industry 4.0 [5]. Resulting digital factories may be at the edge of becoming more efficient from a technological perspective, but vice versa human workers and the social perspective have continuously been pushed into the background and treated as an inevitable evil in many cases. The human potential has so far remained fairly untapped in manufacturing. Changing this circumstance will become a major goal, as implementing really innovative production processes require to really empower human workers.

This paper presents a practicable overview of the industrial challenges derived for combining ICT and production in "Smart Factories", introduced by the project FACTS4WORKERS. At the moment of writing this paper the challenges and the proposed research method had been worked out. The main focus of the paper is to disseminate these challenges and the understanding of a smart factory based on the challenges. The research for solutions for the presented challenges is not content of it and will be part of later publications.

After this introduction and motivation of our research topic, the paper is structured as follows:

- Section 2 presents the proposed idea to develop a "Smart Factory".
- Section 3 explains the industrial challenges.
- Section 4 contributes a conclusion and perspective.

2. IDEA TO DEVELOP A "SMART FACTORY"

The idea of the "Smart Factory" will be demonstrated based on four specific integrated smart factory solutions, which will be piloted and validated inside the factories of real industry partners (FACTS4WORKERS). In summary, there will be these solutions developed according to these four Industrial Challenges (IC). This paper explains the idea of the future development and the proposed research method.

In smart factories, the future production work must be supported by worker-centric tools and methods. A smart factory gathers a large amount of data, processes, and stores information that can be directly valuable to workers, but has to be transformed by using social, semantic and big data technologies into a so-called smart information first. The challenge is to provide the right information to the worker at the right time, and to avoid worker information overload, while providing enough information in order to increase worker productivity. By giving workers useable tools with dedicated worker-computer interfaces that allow them to find, use and contribute to that information on their terms, their effectiveness in doing their job (productivity) as well as aspects of their job satisfaction and motivation can be increased.

2.1 Proposed research method

This research targets technologies focusing on worker needs combined with an application-oriented worker-centric evaluation. A set of Smart Factory Services including worker interface components will be developed and evaluated in the outlined industry cases at the industry partner sites. The project follows a mixture of classical research and development and combines this effort with so-called perpetual beta [7], the underlying development-principle of successful next-generation human-centred platforms like Facebook or LinkedIn (see figure 1).

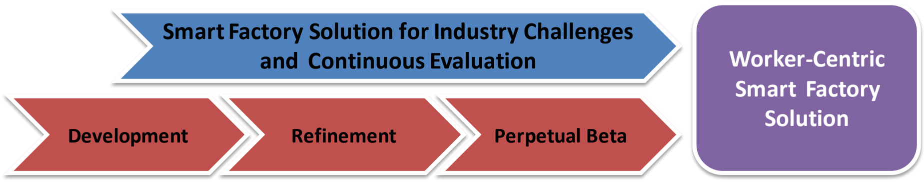

Figure 1 – research method

According to perpetual beta, a software, a platform or an information system always remains in a beta stage, even when being used in a productive way. Successful human-centred development projects follow this paradigm because of its built in agility against user requirements, and users treated as co-creators of software. New features requested by users can be easily slipstreamed to continuously improve the information system according to the users' concrete needs. It is a much more rapid and agile approach to software development, staging, and deployment. Such an approach can also be termed with co-creation, but may not yet been fully adopted in production environments, except on the customer side. The project will adopt this rapid and agile approach from successful user-centered application development on the development of Smart Factory Solutions that are really attractive to workers. This will ensure the worker to be put into the centre. To achieve this goal the project uses the following three phase model, where each phase lasts about one and a third years. Perpetual beta secures a development focusing on worker's needs, wants and expectations, and not only on technological feasibility.

2.2 Comparison of office workers with (manual) production workers

The target is to develop worker-centric tools that assist workers to share information and knowledge so that others can use it in their work, collaborate with co-workers to coordinate work tasks, solve problems and explore opportunities for improvement, assess and manage their own productivity, acquire new skills, and develop existing ones. Such tools may have been introduced in offices with varying levels of adoption and success before, and may have targeted the same task dimensions. But there are huge differences between both work environments:

- Workspaces for knowledge work(ers) are very uniform; desk, PC and phone. Factory workspaces are very diverse and usually contain only some of those elements.
- Offices mostly have "living room conditions", unlike factories where heat, noise, dust, chemicals and moving machinery abound—often requiring protective clothing.
- The main machine in the office (the PC) can be configured to assist in the majority of office tasks. Factory workspaces use highly specialized tools and machines (e.g. lathes, offset presses) to perform location-specific tasks. Task switching in the factory is complex.
- Knowledge workers handle virtual objects that can be copied, transformed and transported easily and mostly reversibly at negligible cost. Factory workers handle physical objects for which this is not the case.

Apart from these physical and task-oriented differences, organizational and cultural differences have to be taken into account too. For example knowledge workers are used to a high degree of self-management — in large part because the productivity of knowledge work is very hard to assess externally. In factories a strong hierarchical management organization has been the norm, and self-management culture is mostly absent. Because of these differences ICT for productive knowledge work in office settings cannot directly be transferred to the shop floor; they will need to be altered. Developing and deploying these worker-centric tools will require expertise not only from the ICT domain, but also from the domains of human factors, work organization, and behavioral psychology. Successful deployment of these tools is very dependent on how they are accepted by workers and management, and how workers are trained to use them to optimum benefit.

3. INDUSTRIAL CHALLENGES FOR "SMART FACTORIES"

Four smart factory industrial challenges serve for demonstration and evaluation of the complete concept in FACTS4WORKERS. Though industrial challenges can only give an exemplary view on a smart Factory of the Future, they are proposed to be transferable to other companies in the manufacturing industry, especially to SME. The four industrial challenges are intended for testing and prototyping the smart factory building blocks at the forerunners' factories and then transferred to the factories of the followers. Taking such an approach will assure a working transfer of the developed smart factory building blocks into other manufacturing industries. These challenges are shown in Figure 2.

Figure 2 – The four Industrial Challenges

3.1 Industrial challenge 1: Personalised augmented operator

Personalised augmented operators are workers using augmented reality (AR) tools through which they get an immediate, specific, visualized, and personalized provision of information at the shop-floor-level, which can be configured according to their needs, roles and preferences.

Due to growing customisation & reducing lot sizes (down to lot size = 1) in production and complex assembly across the entire automotive value chain (e.g. in car interior manufacturing or production of 3D steel and plastic components) operators and production workers need to deal with a growing number of specified and quickly changing information from various sources, while working requires two hands for operation.

A car seat for instance in today's automobiles is stocked with all manner of gadgetry (e.g. seat position sensors for airbag control) and cause a much more complex, rapidly changing production than ever before. In this case the production information comes from various sources: information from roll-form plant, from sophisticated design and diverse suppliers as well as real-time input data from machine sensors.

While Cyber-Physical-Systems (CPS) connect physical and digital production systems, the Augmented Operator grows in relevance. In quickly changing, re-adaptable production lines, when rapid prototyping technologies (e.g. 3D-printing) begin to be introduced in warehouses and on the shop-floor, job descriptions/orders and the interlinked production processes grow in complexity.

However, workers even in the digital age need to rely on paper checklists generated from MES/ERP systems, in order to receive exact job descriptions/orders. In this situation operators may be irritated by information overload while fulfilling the specified working task. Context-relevant information displayed in the line of sight, without media brakes and a seamless interaction across different IT tools becomes crucial for smooth operation and avoidance of cognitive overload.

3.2 Industrial challenge 2: Worked-centric knowledge sharing/management

Current ICT adopted in factories is neither successful in capturing knowledge, nor do they support social interaction and learning. Such knowledge management systems are usually developed for office environments, but shop-floor workers have different needs.

Knowledge sharing in a manufacturing company has the same relevance as in an office environment, but the applicability of ICT tools on the shop-floor implicates a lot of specific requirements, e.g.

- Interaction schemes need to be even more simple & intuitive (e.g. touch or gesture interaction instead of typing) taking into account also extreme conditions in production environments (e.g. extreme heat, noise);
- Tools need to be much more robust (e.g. "rugged devices") and safety needs to be guaranteed throughout whole the production process;
- Data & know-how security as well as workers privacy must be guaranteed.

The industrial challenge consists in introducing "open innovation 2.0" and ICT-supported knowledge sharing practices in such an environment by the most effective means.

3.3 Industrial challenge 3: Self-learning manufacturing workplaces

Self-learning manufacturing workplaces are established through linking heterogeneous information sources from the worker's environment and beyond, and extracting patterns of successful production, transferring the result as decision-relevant knowledge to the worker.

Automotive manufacturing companies are faced with a vast set of demands. Those demands may be very strict and detailed and non-compliancy to any of them may lead to a loss or termination of business deals. Therefore, whenever any unexpected, unplanned or unsuccessful situation on the shop-floor arises, this has a negative impact on the enterprise. In a smart factory an intelligent, self-learning optimization process with the use of an advanced system for collecting product/resources/process data, IT-technology and diagnostics tools and a proper data presentation system with an interface user-friendly for the shop-floor employees is required. The services involved, whether corresponding to material activities carried out by people and/or machines or data-bound processes, are often arranged in a manual way and seldom changed or revised. Automation can allow much more efficient operations dynamically evolving according to actual needs. Their implementation will aid manufacturers to acquire a tighter intelligent and interactive control over workplace, work safety, active protection of workers and economic benefits and enable them to actively monitor and respond to any problems that might arise regarding the machinery and devices they use.

The aim is to identify data patterns in the manufacturing process, which are able to explain e.g. the following questions from practice:

- Where in the manufacturing process and its services do problems/bottlenecks arise
- What service or which person is most suited to react, solve the problem or repair the damage;
- How should a problem be fixed;

- More specifically which faulty component/part of the machine needs attendance;
- How much time will the repair and maintenance process take.

3.4 Industrial challenge 4: In-situ mobile learning in the production

In-situ mobile learning in the production, will develop and demonstrate an on the job learning environment for shop floor workers using rich media through the knowledge management system, which is especially valuable for SME.

Production SMEs in the automotive value chain/network need to comply with a serious number of specific requirements & regulations. Additionally compared to large enterprises, workers do not have always clearly specified roles, but rather need to fulfill very different tasks and share responsibilities in production. This causes the pervasive need of an overall on-the-job knowledge, available on the right-time in the right place.

Workers need context-aware learning in real-life situations („in-situ“, pervasive learning), a field which is still emerging, especially in production settings of SMEs. The establishment of pervasive learning environments has to be based on the successful combination and re-configuration of inter-connected sets of learning objects, databases, data-streams, visualization devices (e.g. digital data glasses) and relevant human computer interaction concepts. The following research questions are addressed in order to overcome the current situation:

- How can in-situ learning services be designed in order to achieve a high acceptance rate by learners and/or trainers?
- What are multimodal input and output interactions as well as interfaces suitable for HCI concepts for in-situ learning?
- How can contextual data be applied for high efficiency and efficacy of context-aware pervasive learning?

4. CONCLUSION AND OUTLOOK

While “Smart Factories” are able to autonomously perform the production process, the worker will still play the central role within future forms of production, as the most flexible element in production. The research work of this paper puts the workers in the focus and therefore it becomes obvious that the best way to support them is to implement approaches with ICT technologies. This approach is suggested by the funded project FACTS4WORKERS. There is enormous potential in providing the right information at the right time and the right place by using modern technologies.

The target impact of this research can be summarized as following:

- To increase problem-solving and innovation skills of workers participating in the pilots
- To increase cognitive job satisfaction of workers participating in the pilots
- To increase average worker productivity for workers participating in pilots
- To achieve a number of worker-centric solutions through which workers become the smart element in smart factories, interacting by deploying a flexible smart factory infrastructure.

Four industrial challenges will be worked out in order to achieve these targets. First it is intended to provide immediately and specifically visualized information to the operator via AR-tools. Secondly a knowledge management system for workers should be developed including open innovation and knowledge sharing facilities. Another target is to establish self learning manufacturing work places to accelerate the analysis process of production parameters and the decision process of the responsible worker. Finally an on the job learning environment for shop floor workers should encourage the workers to learn context-aware in real-life situations to cope with requirements of flexible production.

The next step consists of a detailed development of several ICT solutions for the introduced challenges which will result in a smart factory solution. These solution will then be rolled out as pilot in the different production sites of the industrial project partners. After this roll-out an analysis system will be established to measure the impact of the different solutions against the above goals in order to validate the quality of the research work.

5. ACKNOWLEDGMENTS

This project FACTS4WORKERS has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n˚ 636778.

6. REFERENCES

[1] Ajjan, H., Hartshorne, R., Buechler, S.: *Investigating Web 2.0 Application Impacts on Knowledge Workers' Decisions and Performance*, Information Resources Management Journal (IRMJ), Volume 25, Issue 4, 2012, 65-83

[2] Alexopoulosa, K., Makrisa, S., Xanthakisa, V., Sipsasa, K., Liapisb, A., Chryssolourisa, G., *Towards a role-centric and context-aware information distribution system for manufacturing*, 8th International Conference on Digital Enterprise Technology - DET 2014 Disruptive Innovation in Manufacturing Engineering towards the 4th Industrial Revolution, Procedia CIRP 25, 2014, 377 – 384

[3] Berners-Lee, T.: *An attempt to give a high-level plan of the architecture of the Semantic WWW*, 1998 http://www.w3.org/DesignIssues/Semantic.html, 2014-12-13

[4] FACTS4WORKERS Homepage, http://facts4workers.eu/project/partners/, 2015-03-15

[5] Industry 4.0 is a project in the high-tech strategy of the German government, which promotes the computerisation of traditional industries such as manufacturing. A similar project is carried out by GE, called "The Industrial Internet", http://www.ge.com/docs/chapters/Industrial_Internet.pdf 2014-12-13

[6] Lanz, M., Järvenpää, E., Luostarinen, P., Garcia, F., Tuokko, R.: Towards Intelligent Assembly and Manufacturing Environment – Modular ICT Support for Holonic Manufacturing System, Precision Assembly Technologies and Systems, IFIP Advances in Information and Communication Technology, Volume 371, 2012, 154-162

[7] O'Reilly, T.: *What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*, Communications & Strategies, No. 1, First Quarter 2007, 17

[8] Oikawa, H. *ICT-based optimal plant management solution*, Fujitsu Scientific and Technical Journal, Volume 50, Issue 4, October 2014, 25-30

[9] Paschke, A., Coskun, G., Harasic, M., Heese, R., Oldakowski R., Schäfermeier, R., Streible, O., Teymourian, K., Todor, A.: *Corporate Semantic Web Report VI: Validation and Evaluation, Berlin, 2013*, http://edocs.fu-berlin.de/docs/servlets/MCRFileNodeServlet/FUDOCS_derivate_000000002689/Report_2013.pdf?hosts=local, 2015-03-13

[10] Richter, A., Stocker, A., Müller, S., Avram, G.: *Knowledge management goals revisited: A cross sectional analysis of social software adoption in corporate environments*, VINE, Vol. 43, Issue 2, 132 – 148

[11] Sauer, O.: *Information Technology for the Factory of the Future – State of the Art and Need for Action*, 8th International Conference on Digital Enterprise Technology - DET 2014 Disruptive Innovation in Manufacturing Engineering towards the 4th Industrial Revolution, Procedia CIRP 25, 2014, 293 – 296

[12] Schönberger, V.: *Big Data: A Revolution That Will Transform How We Live, Work, and Think.*, Houghton Mifflin, 2013, 1-243.

[13] Skevi, A., Szigeti, H., Perini, S., Oliveira, M., Taisch, M., Kiritsis, D.: *Current Skills Gap in Manufacturing: Towards a New Skills Framework for Factories of the Future*, Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World, IFIP Advances in Information and Communication Technology, Volume 438, 2014, 175-183

[14] Stocker, A., Richter, A., Hoefler, P., Tochtermann, K.; *Exploring Appropriation of Enterprise Wikis: A Multiple-Case Study*, Computer Supported Cooperative Work (CSCW), Volume 21, Issue 2-3, June 2012, 317-356

[15] Trier, M., Richter, A., "I *can simply..." – Theorizing Simplicity as a design principle and usage factor*, Proceedings of the 21st European Conference on Information Systems, Utrecht, 2013, 1-12.