Computer Supported Collaborative Work in Ultra Personalized Products and Services

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CSCW in UPPS - Computer Supported Collaborative Work in Ultra Personalized Products and Services

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Abstract. How does individualized production look like? This paper proposes a generic vision of a smart factory which is able to produce so-called ultra personalized products (UPPS) in a batch size of one. This means that each customer is able to configure his or her personal product perfectly adjusted to the needs on base of personal data like body scans. As we are convinced that there will always be humans involved in planning and conducting manufacturing processes, we want to highlight the human-to-human interaction and the computer supported collaborative work, which is required in order to set up such a production line.

Current molding machines can only produce one shape per form, all the plastic parts we are using like – for example toothbrushes – have been manufactured in a high batch size, leading to a cheap production of a single part. This requires central production facilities and the distribution to the end users. It is important to know that each new shape is expensive. Contrary to this, 3D printing as production method is developing fast. This process is able to produce a multitude of shapes in a batch size of one. As there are theoretically all possible shapes available in a single machine, this can be used for decentralized production and thus lowering transaction costs. Depending on the specific product, there are still a lot of challenges regarding for example durability, but this process already has started to change manufacturing.

If we regard current production lines, they are optimized for one product, but enable cheap production in a high batch size. Similar to the 3D printer there is the theoretical concept of a "smart factory", which is able to reconfigure dynamically and produce a multitude of different products.

Industry 4.0

Digitization changes the game of communication. While this applies for everyday life as much as for industry, the adaption speed is different. Some people claim, that we are currently undergoing the fourth industrial revolution. According to the definition given by the German government (BMBF (2013)), the "classical" industrialization at the end of the 18th century counts as the first industrial revolution, which has been caused by the innovation of steam powered engines. Counting is continued by means of other great inventions and the accompanied innovation breakthroughs. So mass production and electricity at the beginning of the 20th century is labeled the 2nd industrial revolution. As IT and electronics have already led to large changes in production industry in the 70s of the 20th century, this has been counted as the 3rd industrial revolution. The number 4 is addressed to the current innovation push, which is caused by internet technologies and cyber physical systems.

The international perspective does not always distinguish between those different industrial revolutions. But there is an ongoing discussion about "Internet of Things", "Industrial Internet" and "Cyber Physical Systems", which are closely related to the German discussion. As there are many different definitions in a field with a high influence of marketing buzzwords, a brief summary of the understanding of those terms in this publication is included. The term "Internet of Things" refers to "the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence." (Xia et al. (2012) p. 1101) and is used in several different application fields. Applied on the automation industry, the "Industrial internet" is even described as "Industrial Internet of Things", but also by the promise "to bring the key characteristics of the web – modularity, abstraction, software above the level of a single device – to demanding physical settings [...]."(Bruner (2013) p. 1). Finally, the term Cyber Physical Systems (CPS) "usually comprise a network of physically distributed embedded sensors and actuators equipped with computing and communicating capabilities." (Tabuada (2006) p. 1). This new line of thought wants to understand software, hardware and communication technologies rather as unity (Scheer (2013)) than as different research areas. The term "Cyber Physical System" is used for process modules, whole plants, but also for single individual intelligent products.

The final state of a smart factory with a holistic Industry 4.0 concept is individualized production. The goal is, to reach batch size one while every product steers its production on its own in modularized plants. This should even include the whole supply chain: if a customer selects specific features of a consumer mass product, the production starts to reach exactly this desired configuration. This is possible with flexible supply chain networks and a digital product memory inside the product (BMBF (2013)). Of course, there are branches operating already very closely at this goal description, for example the automotive industry, but it is still a very ambitious goal for small and medium-sized enterprises (SMEs). In order to enable the described reconfiguration capability, future manufacturing systems need digital twins – "very realistic models of the current state of the process and their own behavior in interaction with their environment in the real world." (Rosen et al. (2015)).

Ultra personalized products and services

People are surrounded by products tailored to their specific size and shape: clothes, shoes, spectacles or sports products. In order to be able to massproduce these goods, industry has devised standard size/shape systems. However, existing solutions have a number of disadvantages: there is always a mismatch between the numbers produced and those sold/used, resulting in reduced margins and waste. Furthermore, products designed for mass-production do not match many people's personal needs, even though an exact and personalized fit is essential. There is therefore a need for a radically different approach to product creation. Emerging digital technologies like 3D scanners, cloud services, and advanced manufacturing enable true "mass personalization" (Fogliatto et al. (2012)), which has already yielded some early applications.

Those ultra-personalized products and services (UPPS) require a complete human-centered approach that goes beyond the boundaries of traditional manufacturing industry: it requires adaptation to digital representations and computation-controlled production systems are essential.

An area in which this process is already used is the medical domain, where artificial limbs, hearing aids or tooth implants are already today custom-made for the individual patient. With the advancing technology, ultra-personalized products are possible to an affordable price. Within this paper, we want to use the example of custom-tailored clothes. For a long period in history, this was the standard of textile production: as all the required working steps were conducted by manual labor, the suit or the trousers were made to exactly fit the customer. During the different industrial revolutions, also the way of producing goods has changed a lot and today we are all used to more or less standard clothing sizes in order to buy our clothes. But with the UPPS process, this is already beginning to change. In the future, it is quite likely that we use a 3D scan of ourselves in order to look for fitting clothes, or even exactly define the design of our garment and receive the individually manufactured piece.

The UPPS cycle is defined as Analyse, Design, Produce, Test and Use, whereas the last two can be combined in one step. In the analysis phase of our example, a 3D image of the customer is created. In a second step, the design is defined - in our example the customer might chose the shape, the fabric and the colors. Thirdly, this exact piece is produced in a batch size of one in a production plant. In the last steps, the customer gets his or her product, tries it and starts using it.

The role of humans in smart factories

A central requirement of Industry 4.0 can be derived from the member survey of the Germany's Association for Automation (GMA) in 2012 (GMA (2013)): On the question "Which technical or socioeconomic developments will give the biggest momentum in the next three years?" (translated) the "human machine communication" has been judged as one of the most important factors for future productivity. Despite ongoing automation, humans will still be present and also highly necessary in tomorrow's production factories: 96.9% of the questioned enterprises of another study (Spath et al. (2013)) judged the importance of human work in five years still as "important and very important".

This is a clear contrast to the ongoing fear, that Industry 4.0 replaces all human labor. Moreover, also leading roboticists confirm this – recently, (Sheridan (2016)) stated: "All robots for the foreseeable future will be controlled by humans". Thus, in the current fourth industrial revolution the new built smart factories will certainly not be fully automated machine halls, but rather need new approaches for human robot coproduction. Especially the trend of ultra personalized products and services require batch size one and require a higher flexibility of robot operated manufacturing and create a real need for human robot coproduction on the same product.

Altogether, this motivates a closer look into the dynamics between humans and machines in the context of the forth industrial revolution and ultra-personalized products and services. The research field associated with human-to-human communication via network is called "Computer Supported Cooperative Work" (CSCW). There are numerous definitions of this term. We use the following definition translated from Gross et al. (2007): "CSCW is research on possibilities and effects of technological support for humans to work and communicate in groups and work processes".

CSCW in UPPS

But how does individualized production look like? The UPPS cycle consists of the steps Analyse, Design, Produce, and Test and Use. The scheme depicted in Figure integrates this view together with the manufacturing perspective, covering both the end customer journey (the person buying her or his custom-made garments) and the enterprise customer (who is for example responsible for the entire line of clothing).

The generic vision of a smart UPPS factory requires computer supported collaborative work. If we start with the end user, we build a digital twin of this human by gathering data, for example by conducting a body scan (Analyse phase). The end user can chose between some designs – like skirts, shirts or trousers –

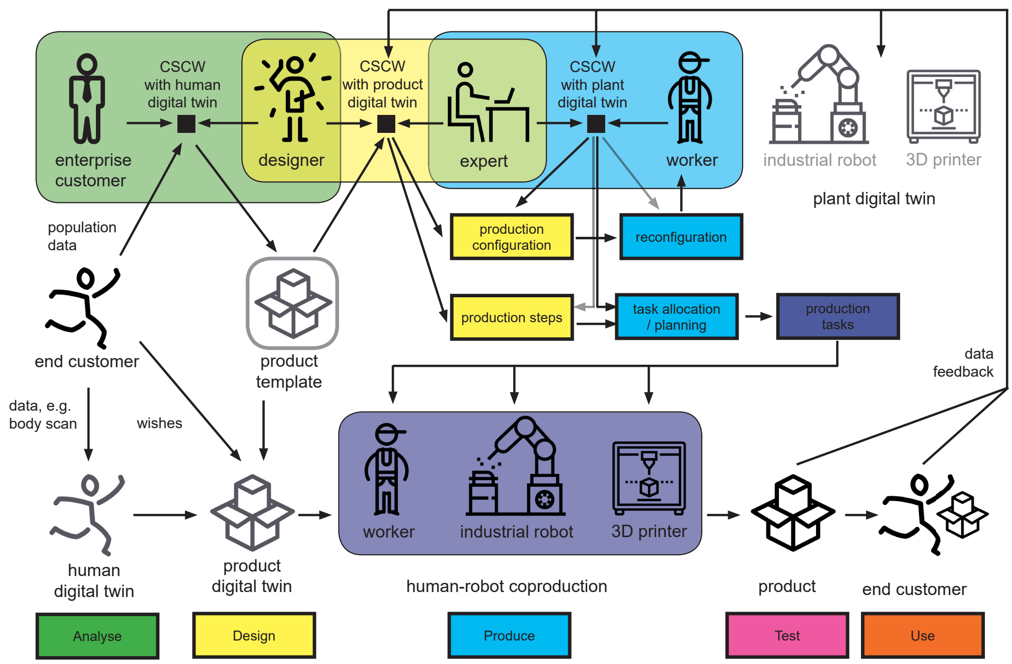

Figure 1. Generic UPPS scheme.

representing product templates. The end user can alter those templates according to her or his wishes and instantiate the template with the body parameters. This results in a digital twin of the product, because it is not only a design, but also already contains real measures (Design phase).

The production line has been set up already for this specific type of product templates, a process we will cover after the end costumer journey, and is able to manufacture the desired product (Produce phase). The real product is then tested within the factory and eventually with the customer (Test phase). Then, the end customer starts to use the product (Use phase).

The second customer journey is the more complex process of setting up a UPPS production chain for a specific set of product templates. This starts with the wish of an enterprise customer, for example a clothing company. Together with a designer or multiple designers, the specific set of product templates need to be generated. This will be a computer-supported collaborative work process bridging the Analyse and the Design phase (highlighted in green). This discussion is carried out with the help of a generic digital twin of a human generated by population data. This includes already the possible variety of different humans (like for example body height) but also general limitations (for example the maximum angle a specific limb can be moved).

Collaboration is further required, when the designer discusses the properties of the product templates with the manufacturing expert in a cooperative space (yellow), so that they can derive the desired production configuration and the production steps. As all of the population diversity of the human digital twins need to be able to be represented, a continuum of product digital twins is regarded here, which encompasses all possible configurations.

The expert uses another virtual cooperative space (blue) with the worker at the factory. With the help of a digital twin of the production line, they plan the production setup for each of the possible product digital twin options, decide upon necessary reconfiguration steps and can discuss maintenance and optimization issues. Furthermore, the production steps are mapped to tasks for worker and machines. If this discussion has been solved, the planning process for that specific set of product templates has been finished.

The plans of the digital twin of the plant can then be used in order to built a configuration necessary for the specific digital twin of the product requested by the end user. This does not necessarily mean, that the entire production is reconfigured for each product – it will rather lead to trying to congregate similar settings in a complex scheduling problem. The solution could be, for example, that for the next two days, only skirts are produced. Then the necessary configuration of worker, robot and other production machinery (here a 3D printer) is built, but still the specific production steps may differ from one product to another, as for example different sizes of skirts in different colors are produced.

The last but crucial component of our scheme is the data feedback. The real products may itself contain internet of things items like wearables and be able to gather data. Furthermore, data from the tests or the user feedback can be gathered. This data is needs to be fed back into the digital twins – in order to make the production process more robust, the products more durable or also to be able to design new kinds of products.

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