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Retrofit Concept for Textile Production

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Abstract. In production, an intelligent analysis of the data provided along the production line bears huge potential for increasing process efficiency and reducing production costs. The (continuous) collection of relevant data is a crucial precondition for every Industry 4.0 or smart technology. While new machines have internal controllers and sensors to meet those requirements, this is usually not the case for machines being already in use. Especially in the textile industry, it is often standard to keep old machines since the manufacturing methods themselves haven't changed significantly over the past decades. Hence, the successful exploitation of digitalization advantages requires these companies to first develop and implement a digitization strategy. In this paper we present a concept which allows to develop modular, scalable, flexible solutions considering the whole digitization process from data acquisition to storage. The concept is complemented by a guideline for its application in industry. Experience from a prototypical application in a textile company is described. The concept enables companies to determine the various conditions and requirements for digitization, to analyze different possibilities and to deduce scenarios that lead to a solution for the effective utilization of Industry 4.0 technologies.

Keywords: Industry 4.0, textile process chain, modularization, digitization, digitalization.

1 Introduction

Being one of the most important trends of our time, digitization and digital transformation are the key for production companies to secure their long-term competitiveness. Industry 4.0, a synonym for the digitalization process, provides new opportunities for optimizing the entire value-added chain [11]. A modern IT infrastructure, digital applications as well as intelligent data and networked systems are the decisive factors for the fourth industrial revolution. In this context, the following two aspects have to be considered. First, the available standard digitization solutions do not apply to every sector (in Germany, best practice solutions usually aim at the dominating sectors of automotive and microelectronic industry). Second, the fitting accuracy of existing solutions to small and medium-sized enterprises (SMEs) is generally not considered. However, SMEs are an important economic factor in Germany as they make up more than 99 % of all enterprises [15]. Especially in the textile sector, one of

the oldest industries in Germany and still of vital importance for manufacturing high-quality technical textiles as well as custom products, the majority is SME [12]. We want to close this gap and develop tools that enable the textile production SMEs to be digitized, to adapt to the fast-paced change and to benefit from the advantages.

The paper is structured as follows. Section 2 comprises an investigation of the relevant aspects of the textile industry and an overview of the digitization process we want to implement. In Section 3, we deduce the requirements that our solution has to meet in this context, derive the concept and propose a guideline for a proper application in the industrial environment. The paper concludes with the results of a prototypical application of the concept as well as an evaluation of the obtained knowledge.

2 Theoretical Background

2.1 Preconditions of the textile industry

In order to establish a concept for the digitization of textile companies, it is crucial to analyze the prevalent procedures, methods and manufacturing facilities. As relevant fields, filament and textile production and textile finishing were identified. The linked procedures (and, hence, machines and technology) vary strongly, as Table 1 shows.

Table 1. Procedures and relevant parameters in textile production

Field	Product (selection)	Procedures (selection)	Relevant parameters (selection)
Filament production	Natural fibers	Preparation (carding, drawing, combing), spinning process	Air flow, heterogeneity of the fiber
	Synthetic fibers	Preparation (liquefying raw material, wet/dry/melting procedure, drawing), spinning process	Type of separation, spinneret pressure
Textile production	Tissue	Preparation (spooling, twisting, sizing, warp beam provision), weaving (rapier/air jet/shuttle)	Thread stability
	Knitted goods	Thread provision, structure formation	Thread tension, thread velocity
Textile finishing		Preparatory treatment (brushing/tapping/singeing, washing/bleaching), dyeing (padding and exhaustion; for synthetic fibers: within preparation process)	Temperature and chemical composition of the dye, direction of the good

The process parameters of and even within the three production fields differ in most cases, which means that it is not possible to identify universal parameters as a baseline. As a consequence, the concept has to be very abstract in order to provide a common guideline for the different textile production procedures and heterogeneous machinery. Since most of the basic operating modes in textile production have been established years ago and still prove to be state-of-the-art, the machines are generally not equipped with control units or sensors for gathering data. Accordingly, the inter-

nal IT infrastructure is not fully digitally evolved, implying that data measurement from the viewpoint of digitalization is insufficient (which is characteristic for SMEs [8]). This leads to two main tasks: appropriately equipping the machinery and improving the IT infrastructure. Particularly, retrofitting of the “digital process chain” (collect, transmit, save and make data available) is part of the main goal. The purpose of retrofitting “is to transfer the aspects of the Industry 4.0 visions to machines and processes with the least possible financial and time expenditure” [6].

2.2 The process of digitization

It is our goal to transform the analog world of the textile companies into a digital one, i.e. to map the relevant data into a digital model, on which then a defined action is performed. According to [7, 14], this process is defined as digitization, which has to be distinguished from digitalization: the latter one corresponds to making use of the data gathered within the digitization process. Digitization builds the basis for digitalization. The gathered data should be stored in a database in order to have access to relevant information for evaluation and to possibly share it via Internet of Things (IoT) systems. Hereby, the focus is set on condition monitoring as the basis for optimizing the production process as it is one of the most important and profitable topics.

The digitization process consists of the three steps collecting data, transferring data as well as storing data [16]. We have to adjust them to our problem, and then a method for a proper implementation has to be formulated.

3 Methodology

3.1 Requirements

Starting point of developing the concept is the deduction of the requirements it has to meet. Based on the knowledge gained about the textile sector in combination with digitization and our interviews with textile companies, we identified the five main requirements modularity, scalability, open interfaces, data security and technical flexibility. In the following, they are explained and investigated w.r.t. this paper’s context, hereby providing a deeper understanding and the fundamentals for the concept.

Modularity is described as “a structuring principle which enhances clarity, reduces complexity, provides flexibility and has some organisational advantages” [9] and demands for both separability and functional independence. Separability addresses the possibility to interchange certain components without negatively affecting the system as a whole. The second dimension, functional independence, assigns a uniquely defined and self-contained task to every component. The main advantage of modularity is the high flexibility of the digitization solution w.r.t. extension and substitution.

Scalability, “the ability of a system to accommodate an increasing number of elements or objects [...] and/or to be susceptible to enlargement” [1], can be understood in a vertical (i.e. increasing performance by improving/upgrading the system without raising the number of modules) and a horizontal way (in the sense of achieving increased performance by adding components, e.g. gradually digitizing the company).

The next requirement, *open interfaces*, stems from the goal of retrofitting the textile machines. It is defined as the ability to include data from various sources and combines them into a consistent system [4]. For the realization of Industry 4.0 applications, an integration of the machines into the IT infrastructure is mandatory as well. Because of the heterogeneity of the textile machinery, numerous different systems with varying data sources need to be linked.

Data security, defined as a set of standards and technologies that protects data from intentional or accidental destruction [3], was identified as one of the main obstacles in the process of the digital transformation of SMEs [17].

The users' claims, varying strongly due to the wide range of the processes and machines, call for *technical flexibility*: the concept has to be capable of including both easy in-house developments and highly advanced, industry-standard solutions.

The five requirements have to be fulfilled throughout the digitization process. In addition, we want to achieve a high abstraction level such that the field of application meets the diversity of the textile production processes.

3.2 Derivation of the concept

First we have to ensure that the three steps collecting data, transferring data and storing data as the basis of the digitization process fulfill the five abovementioned requirements. Data collection combines the different functionalities of acquiring signals as well as converting them into measurable information and, as a consequence, might contain parts of data transfer. This contradicts the required functional independence. Hence, we divide data collection into the two parts acquisition of a physical value and conversion of the signal (both will be connected via data transfer). This is especially necessary in the context of retrofitting, i.e. equipping machines such that a digital signal or an interface for data transfer is supplied. Having a closer look at data transfer and data storage, we conclude that a further separation is not expedient.

Figure 1 depicts the results obtained so far: in order to meet the requirements explained in Section 3.1, we derived five functional sections of the digitization process in a logical order. Every section is strictly separate from the adjacent ones, modularity and scalability are fulfilled. The latter three requirements (open interfaces, data security and technical flexibility) will be significant w.r.t. the content of the five sections.



Fig. 1. Five sections of the digitization process

We will now use this fundamental structure to develop and explain the modules that form the sections. Those modules correspond to the means and ways of how to realize the action that has to be performed on the data. For every component to be digitized (e.g. a machine), suitable modules within each section have to be chosen.

Considering the sector acquisition, we identified the relevant modules sensor, control and manual input. The module sensor, a crucial tool for retrofitting, establishes a

connection between a physical quantity and, generally, an electric signal. Since we aim at high technical flexibility for the diverse textile machinery, a division of sensors with and without industry standard is reasonable. The module control, comprising control units already integrated in machines to gather data, is important in the context of retrofitting: it has to be distinguished whether the control provides data or not. This allows the user to identify controls that need to be equipped with an extra module to guarantee the desired functionality. The module manual input covers data that is included in the system manually, with the help of a special device or a software.

The sector transfer comprises wired and wireless, which both occur in textile factory halls. To meet the company's demands on the requirement data security, encrypted and non-encrypted transfer is distinguished. Here, encryption refers to a technical solution that protects data classified as critical against unauthorized access.

The tasks of the sector conversion & measurement generation usually are fulfilled by a powerful computer. Depending on the digitization goal, additional controlling beyond the possibilities the machines provide is in need. The relevant modules are micro-PC for easy controlling tasks, programmable logic controller (PLC) to control one special machine, IoT gateway mainly for forwarding data and industrial computer as high-end solution for complex tasks as well as controlling many machines. Considering that retrofitting machinery in the textile industry is our main task, open interfaces (especially w.r.t. the two adjacent sectors data transfer) must be given throughout the whole chain of collecting, processing and storing data.

The sector storage comprises modules that ensure the long-term storing of the acquired data in a secure way. The two prevalent concepts are cloud (private or public) and server (centralized or non-centralized). Note that cloud computing has been identified as one of the key technologies for digitalization initiatives [2], but at the same time the safety standards imposed by the company have to be met (see Section 4).

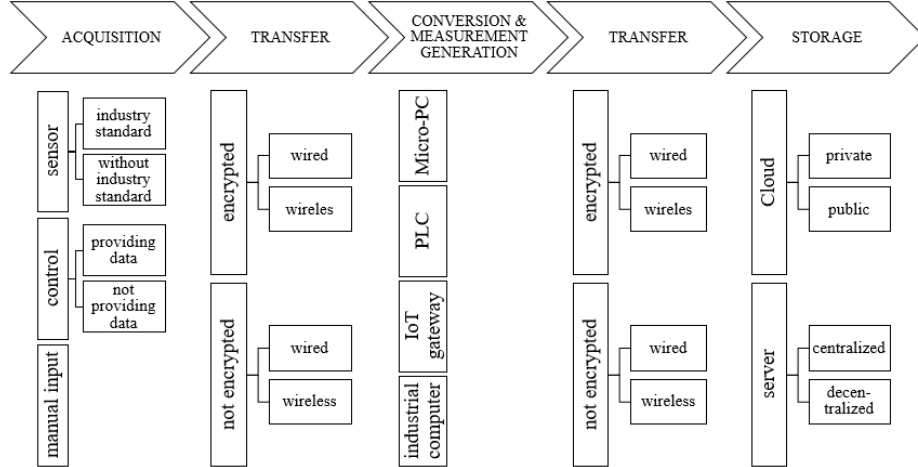


Fig. 2. Concept sections and corresponding modules

Figure 2 visualizes the obtained results. The concept, following the five identified sectors in a logical order, forms the basis of the development of the digitization solu-

tion, which is realized by selecting the proper modules within this chain. The desired high abstraction level is achieved and offers a broad spectrum of application within the textile production industry. We suggest that for a specific application in a company, the abstraction level of the concept is reduced by identifying and selecting the available and relevant technical solutions within each module. This leads to a specification of the modules and provides a more tailored, transparent solution [10].

3.3 Guideline for concept application

Because of the modularity of the concept, a variety of combinations arises as possible digitization solutions. However, since a company is only interested in one very suitable solution, a multi-stage procedure, depicted in Figure 3, is applied: First, both the present and the desired state w.r.t. the five requirements have to be determined. Here, the company's specific goals have to be taken into account (for example, enhancing the internal IT infrastructure or implementing a cloud solution). In the next step, the technical conditions of the company (e.g. availability of a network) are identified. Then, the user repeatedly passes through the five sections of the concept, starting with acquisition and ending with storage. With every cycle, a new component of the company (e.g. a machine) is included. This corresponds to the horizontal scalability of the concept. As a last step, an improvement cycle is performed, which helps detecting previously unrecognized optimization potential. This is justified for example by the broad overview over all modules that are included now, or the optimization potential may occur late in the process due to the gradual integration of components which has not yet been revealed. It corresponds to the vertical scalability of the concept.



Fig. 3. Guideline for the application of the concept

4 Experience from practical application and conclusions


In order to validate the applicability of the concept and to detect chances for improvement, we performed a test in a small-sized German textile company. In coordination with the production manager, we selected part of their machinery with no control unit and no sensors, i.e. machines specifically in need of retrofitting. We then tested the concept together with the production manager, the maintenance manager and the company's IT expert. First we introduced the concept and the intended procedure with the help of visualizations similar to the ones depicted in Figure 2 and 3, respectively. The employees explained the current state as well as the specific goals the company pursues so that we could deduce the desired state. In this case, the company aimed at measuring the machines' temperatures in order to deduce the state of operability (which was currently estimated by employees). The IT expert outlined the prevailing technical conditions, which revealed that data security is a major concern:

cloud solutions were not an option. Based on this knowledge, we applied the five sections of the concept for every machine that was considered to deduce the proper modules: temperature sensors, PLCs, storage via a centralized server and encrypted wired transfer between the units. In the final optimization step, we addressed measuring the ambient temperature via an additional sensor. The actual usage of the gathered data as the result of the digitization process was also an important topic of the discussion and is supported by the concept's modularity: we were able to choose solutions that reflect the usage of the data (e.g. displays for visualization of sensor data).

The validation was successful (the company even intends to realize this solution and outsourced it to their electronic contractor) and allowed us to draw the following conclusions. Decoupling the detection of the present state and the technical conditions turned out to be useful: it helped the employees making deductions from the present state and not focusing on current technical restrictions. Including all decision-makers of the different involved departments proved to be important. Internal processes and conditions (e.g. directives from the works council or for data security) are crucial for a valid implementation and have to be considered. Furthermore, we found that even though we aimed at formulating the concept self-explanatory, a dialogue with responsible company members is indispensable for a successful digitization process: the company's process knowledge in combination with our digitization experience and an unbiased view from the outside leads to a solution-oriented exchange. According to a study [13], German companies lack structured strategies to implement Industry 4.0 solutions. This was confirmed during the real-life test. However, the test also revealed the general huge interest of the managers in the company's digital transformation. The concept turned out to be a very helpful enabler for this process: the discussions led to many valuable digitalization ideas that the concept was able to reflect.

As it became apparent, the expendability of the concept from a so far restricted focus on the machine to tracking, tracing, localization of products and orders, process parameters, knowledge in manufacturing planning and control seems to be possible with only a few adjustments and will be part of future research.

From the high abstraction level of the concept (which was necessary due to the diversity of the textile production processes), we can deduce two important aspects. First, the typical fears and wishes of companies – they want to implement solutions that are low-cost and easy to understand [5] – can easily be met due to the modularity, technical flexibility and scalability of the concept: it provides a classification of the modules, whereas the final technical solution is subsequently selected in coordination with the company (this was indicated in Section 3.2). Second, the high abstraction level is likely to allow the transfer of the gained knowledge to other fields of the production industry. This will also be part of our future research.

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