

Special Issue – Case Report

Andrea Altepost*, Mario Löhrer*, Nenja Ziesen, Marco Saggiomo, Niklas Strüver, Daniel Houben, and Yves-Simon Gloy

Sociotechnical Systems in the Textile Industry

Assistance Systems for Industrial Textile Work Environment

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Abstract: This article delineates the work of an interdisciplinary research group concerning the implementation of a digital assistance system in the German textile industry. Using a holistic approach, researchers from different disciplines contribute to the design of an integrated socio-technical method that guides industrial actors in developing and implementing digital assistance systems that are applicable on the shop-floor level and at the same time take into account various social and organizational demands. Following this approach, the development of new technologies is coordinated with innovative social practices, for example, learning techniques or organizational changes. Furthermore, aspired users of the assistance system participate in the project by contributing their expertise of the working progress as well as by defining requirements essential towards addressing the various challenges at hand. The conceptual outline and early findings of the project, including the development of a prototype of the assistance system, are presented in this article.

Keywords: Sociotechnical systems, assistance systems, Industry 4.0

1 Introduction

With Industry 4.0 concepts approaching shop floors, the German textile industry is forced to face real technical and social challenges. Mainly shaped through small and medium enterprises, the textile sector is now confronted with a trend of growing automation and interconnected production lines and value-added chains. This trend corresponds to a decreasing relevance of large scale production in favour of smaller lot sizes. Cyber Physical Production Systems (CPPS) [1], electronic components, sensors and control modules conjoined with new communication elements change handling and maintenance actions of production equipment and processes. The profession of textile machine engineering is going to rely heavily on wireless and web-enabled sensors to monitor relevant process variables [2]. Therefore, an important question is whether and how interconnectedness and integration of digital elements will change work processes and will require new competences in regards to human-machine interaction.

At the same time, the present structure of the textile industry is strongly pressurised by the demographic change: the proportion of workers above 45 years of age is higher than the current average [3] and a shortage of skilled workers and successors to the retiring workforce [4, p. 32] can be identified in Germany, which necessarily affects the textile industry. Also migration – in the years 2015 and 2016 alone 1.85 million people immigrated to Germany [5] – will ultimately increase the diversity and heterogeneity of the German workforce. To remain its competitiveness, hence, it is crucial for the textile industry to consider aspects such as – among others – age, gender, language and cultural background as relevant for their modes of production.

Accordingly, these developments pose the question of how to connect the necessary technological innovations with existing social practices and working experiences of an increasingly heterogeneous staff. In order to generate new and adequate social courses of action, for example new forms of organizational communication and on-

*Corresponding authors: **Andrea Altepost**, **Mario Löhrer**, Institut für Textiltechnik (ITA) der Rheinisch Westfälische Technische Hochschule Aachen University, Aachen, Germany, e-mails: andrea.altepost@ita.rwth-aachen.de, mario.loehrer@ita.rwth-aachen.de

Nenja Ziesen, **Niklas Strüver**, **Daniel Houben**, Institut für Soziologie (IfS) der Rheinisch Westfälische Technische Hochschule Aachen University, Aachen, Germany, e-mails: nziesen@soziologie.rwth-aachen.de, nstruever@soziologie.rwth-aachen.de, dhouben@soziologie.rwth-aachen.de

Marco Saggiomo, **Yves-Simon Gloy**, Institut für Textiltechnik (ITA) der Rheinisch Westfälische Technische Hochschule Aachen University, Aachen, Germany, e-mails: marco.saggiomo@ita.rwth-aachen.de, yves.gloy@ita.rwth-aachen.de

the-job-learning, therefore, technological change must be comprehended only in its connectedness to social innovations. We regard social innovations as preconditioning, accompanying and consequential phenomena of technical innovations [6], since they are primarily concerned with a goal-oriented reconfiguration of social practices by actors to achieve a better or socially more desirable problem-solving method [7]. For example, as a new, heterogeneous workforce is in need of imparting qualifications and experience-based knowledge, innovative ways of learning and knowledge transfer are required. Tasks like this – and sociotechnical innovations in general – demand not only technical knowledge but also expertise in organizational developments and social aspects. In order to accomplish those tasks, it is reasonable to bring together professionals from different disciplines. Learning processes, for example, have to be designed, initiated and accompanied by professional educational support if they are purported to be sustainable.

Hence, only through a holistic, systematic approach the manifold interdependencies between organizational, technological and social changes of human-machine-interaction in production environments will become discernable and thus controllable [8]. For these reasons, an interdisciplinary team of researchers was implemented at the Institute of Textile Technology of RWTH Aachen, consisting of specialists from engineering, sociology and education sciences in order to conduct the project “Sozio-Tex – New sociotechnical systems in the textile industry”, granted by the Federal Ministry of Education and Research. The project aims at the development and implementation of a digital assistance system for weaving mills, which supports workers heterogeneous in age, gender, qualification and cultural background in adapting to varying contexts and scenarios concerning Industry 4.0. By accelerating and simplifying learning and performance, for example, conducting a warp beam change, the research group expects a growth of productivity of about 30%. From the very beginning of the project, the prospective users – managers and employees of three weaving mills in Germany – were integrated into the requirement analysis and design process, by taking part in workshops, surveys and group discussions. This participative approach in systems design not only helps to address possible concerns and objections, which eventually would inhibit the implementation of digital or technical devices on the shop-floor. Moreover, it also makes use of the expertise of the employees to gather all information available to achieve a functional and accepted solution [9, 10].

This project report initially describes the methodical approach of this project. Subsequently, the proceedings of

the work phases conducted by the project team till date are illustrated. Beginning with the requirement analysis, we then elucidate steps of user oriented conception of an assistance system. These include work process- and workplace-analysis as well as several sub-steps of systems design. This leads us to upcoming decisions on hardware and software questions and the implementation of a prototype version in a laboratory environment in connection with a first user test. The conclusion section sums up the most salient aspects of the research initiative.

2 Methodical Approach

This section introduces the methodical approach employed for conducting this project. In regard to the choice of method and profitability [11], the current research is based on a combination of systematic approaches and methodical designs which are borrowed from engineering, social sciences and education sciences.

This leads to an approach (see illustration below in Figure 1) that is designed along the phases of the methodical framework of systems engineering as an engineering approach to systematically analyse and solve problems. Systems engineering combines models based on systematic thinking and well defined procedures into a problem-solving system reinforced in engineering sciences. For the development of an assistance system from a sociotechnical point of view, it has to interact with methods of social sciences in order to address the development of social practices as described above. So each engineering phase is guided by the participation of prospective users and stakeholders, employing a broad scope of social science resources for data collection (as surveys, group discussions or expert interviews) and evaluation.

Based on the resulting phase logic, the approach adopted for this research project (Figure 1) is designed for the development and implementation of sociotechnical systems in general and here is utilised for the developing of an assistance system. In the system engineering phase concept, the processing of a problem situation precedes the so called “kick-off” phase. This phase marks the period from the occurrence of a problem to the decision to do something to cope with the problem [12]. As a sign of problem awareness, previous studies carried out are used, e.g. on demographic change in German society. The results of this scientific study are also found in the preliminary study.

The preliminary study aims to analyse the limitations of the problem field and the design area, in this case the

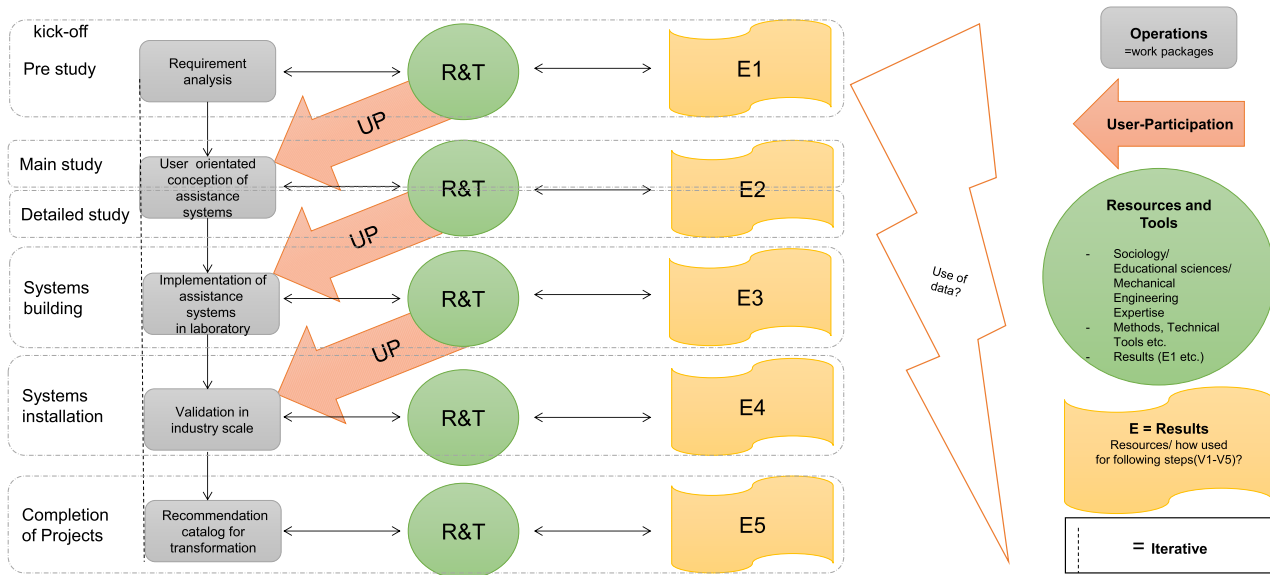


Figure 1: Methodical approach for designing sociotechnical systems exemplary on assistance systems.

German textile industry, as well as to identify requirements and to summarize them in a requirement catalogue (chapter 3). The participative approach of our project implied to conduct the requirement analysis along a multidimensional design (chapter 3) in cooperation with the prospective users. In this way, their ideas of social practices concerning the collaboration with the assistance system were introduced into the conception of the technical design. The main study focuses on the development and refinement of a solution concept by concentrating on the field of observation based on the preliminary study. For this project, this identification of key parameters consisted of the selection of the product change as a set-up work process. This process was systematically analysed and evaluated in terms of manual activities performed and the use of tools (chapter 4.1). As a result, critical activities which required support were derived. During this work step, the forms of assistance which were suitable for assisting critical activities were examined simultaneously. The results of this step were described in a morphological box which matched single work activities and suitable forms of assistance and thus serving as a foundation for the development of assistance system concepts. Subsequently, a value analysis was conducted to compare and evaluate those concepts. Its results led to the selection of an assistance system concept to be implemented in the further research of the project team. Within the framework of the detailed study, the point of view was further limited and work process- and workplace-analyses were carried out in three weaving companies, with focus on product change

as central work process during ongoing work. Here again, the users' preferences and needs concerning functionality and ergonomics were analysed. This was achieved by extensive work process observations and subsequent interviews with workers.

By taking into consideration the results of the preliminary, main and detail studies, concepts for the overall assistance system with its subcomponents (chapter 4.2) and a qualification concept were developed. At the end of the development phases (preliminary, main, detail studies), concept decisions were made, which are then followed by further development and implementation steps.

The aim of the system construction is the implementation and evaluation of experimental prototypes (chapter 4.2). From the synthesis of these prototypes, a complete assistance system is developed. During the phase of system implementation, the assistance system is realised in a real-world condition lab, the textile learning factory 4.0 in Aachen, Germany, where it will be validated through user studies before being transferred to an industry scale.

A recommendation catalogue for the design and implementation of assistance systems with the example of textile production will be drafted as project completion for the transfer of the project results. Furthermore, the implemented assistance system will be used in the learning factory 4.0 for transfer activities such as workshops or training courses beyond the course of the project.

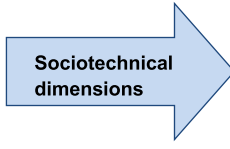
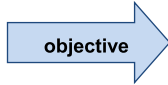
 Sociotechnical dimensions	Assistance systems 4.0 in textile production serve as*:
 objective	Intelligent tools, • real-time operating and internet connection included, • within digitized production settings, • to adequately deliver task- and situational-related support and competence-buildup in the textile process chain**
 Temporal	Instruments • analyse current and • to forecast future utility conditions
 Social	Adaptable human-machine applications and interfaces • for heterogeneous user-groups • enhancing physical and cognitive capabilities

Figure 2: Key dimensions of assistance systems 4.0.

*following VDE 2008" [16].

**focus of the project: production, weaving mills/weaving machines.

3 Requirement Analysis Regarding Assistance Systems

An assistance system is supposed to increase productivity by prolonging the main processing time duration and reducing secondary processing and breakdown time durations. Further, from the holistic perspective delineated in chapter 1, a catalogue of requirements for the assistance system used as support for the employees and the human-technology interaction in the textile sector [13] was drawn. It was generated by a wide range of empirical methods of social sciences such as literature review, surveys, guided interviews, group discussions and observations in weaving mills, workshops and feedback by experts from the companies as well as industrial and scientific advisors. After identifying the relevant dimensions of assistance systems, some salient examples of requirements are introduced.

As a working definition, the research group understands assistance systems as (intelligent) technical aids, with a supporting and, in this case especially referring towards machines, capable-assisting character. The term support represents a relation between human and technology within an action in which the technological support contributes a constitutive role to the action. This contribution may manifest itself in various forms, assistance – eas-

ing the execution of an act – being one of them [14, p. 78]. In contrast to what is generally implicated by the term support, assistance is centred on the fact that the interacting human and technological artefacts (in any shape of form) are able to establish a relation of recognition between each other. This necessary recognition of action emphasizes an observational focus on human-technology interactions. In addition, assistance systems are characterized by a development of production and work in the context of Industry 4.0. This is achieved by integrating different components, such as sensors, actuators and information and communication tools, in a system which is used autonomously by humans [15]. Such assistance systems have three core dimensions with different variances and specifications depending on the presented system: the factual (objective), temporal and social dimension (Figure 2).

They include technological, organizational, human and legal aspects which were addressed by the assessment of requirements. In sum, a literature review procedure, enterprise inspections, workshops, expert interviews, information technologic and mechatronic machine investigations were carried out with the results being evaluated by the researchers in their respective disciplines [17, 18].

From the human-centered, or respectively, from the user's point of view, the qualifications to be learned in dealing with digital tools were emphasized, taking into

account different degrees of digitalization as well as general usability (DIN EN ISO 9241-110 norm [19]), such as task adequacy, self-descriptive design, controllability, expectation conformity, error tolerance, individual customizability and learning conduciveness. For example, the technical design of the assistance system provides individual user profiles that address individual states of knowledge and expectations. To meet the demand of the workers to provide information for machine monitoring, machine data are collected by the assistance system and the information is actively pushed to the user interface device. The technical specifications resulting from these requirements are treated in chapter 4.2. The requirements identified in the field of competence development and the promotion of learning, primarily focus on the need for knowledge transfer and on the possibilities of entering knowledge into the system through internal and external experts (for example, experienced employees, machine manufacturers). Potential learning units must be presented in a customized and problem-oriented manner adapted to the user's knowledge. Furthermore, an assistance system should provide feedback and information, e.g. in the form of a result feedback, to facilitate the assessment and optimization of employees' own work results. As already mentioned in chapter 2, the product change process was identified as an example of critical and time-consuming tasks.

With regard to the identified legal aspects of work and safety, the investigations revealed that there are major gaps in standardisation that still need to be addressed for assistance systems in an Industry 4.0 context, such as data transfer, data protection, etc.

To complete the catalogue of requirements, organizational aspects and procedures to be supported – e.g. communication networks – as well as possible organizational changes are currently discussed with the involved institutions. All relevant requirements are included in prototype versions of the assistance system and will be tested by prospective users in an iterative process (chapter 4.3).

These exemplary results are part of a comprehensive requirement catalogue that includes technical, organizational, human-centred, and legal aspects which must be met by a learning-promoting, (technological) needs-based assistance system in order to support work tasks, processes and structures.

The process of identifying work processes which need support as part of the detailed study in the frame of systems engineering (chapter 2), stress factors and critical tasks using the example of working with weaving machines is in detail presented below.

4 User Oriented Conception of an Assistance System

4.1 The Weaving Machine as Operation Site for Assistance Systems

In the context of a workplace- and work process-analysis in weaving mills, the work process of the warp beam change – as a core process of product change – is a highly complex action since it consists of a multitude of 55 different single steps. Therefore, it was specially examined as a central task during on-going working operation in three weaving mills. The observed weaving mills produce raw and finished fabrics for various technical textiles and applications, for example, in the fields of professional clothing, construction, mechanical engineering and transportation industry.

As a key tool for the documentation and analysis of the warp beam change, a partially structured observation guideline was used which allowed the recording of the work process steps with a focus on (potential) existing stress factors [20]. The documentation of the work process was carried out by using stationary as well as mobile video and photo cameras. Moreover, measurements of room parameters such as distances between machines and the width of corridors used by employees were taken. Also, a multimeter was employed to further measure spatial factors such as temperature, humidity and loudness.

In order to obtain further information about the observed workers and their activities, observation interviews were carried out, contrasting and adding to our pure observations [20, p. 8-9]; [21]. Since the research focus is a user-driven development of assistance systems, the subjective impressions gained in case studies are central to a requirement assessment, as well as acceptance of an assistance system to be implemented [20, p. 9]; [22, p. 78 ff.].

Among other topics, the participants were asked to assess a range of possible interfaces with regard to their potential for assistance of the work process. The toolset was developed within several project-internal workshops. As a pre-test, a laboratory study at ITA (Institute of Textile Engineering), RWTH Aachen University, was conducted.

From the results obtained, it can be stated that an assistance system in the form of a tablet app, as a result of a wide range of possible applications and functions, is particularly recommended for activities carried out on textile machines, especially in the process of the warp beam changing. Central functions of such a supporting assistance system related to this task, should include operating instructions and auxiliary visualization of the working

steps, programming for the automatic height adjustment of the hydraulic lifting device based on the process steps, as well as locating and rating functions and motion detection. Moreover, mobile and factory-wide access of historical machine data turned out as a feature desired by operators. The results also accounted for the demand of assistance in production monitoring, as well as a communication tool appropriate to the loud environment of work in the weaving mill.

Here, an in-ear-device could also serve as a support supplement to the tablet app [20]. Further requested functions concern digital placement of orders and shift scheduling [20, S: 31f].

Another important aspect of the results is the necessity to design self-learning elements for the professions that require training in textile areas as well as storage and transfer options of (experience) knowledge in an assistance system such as the tablet app [20, p. 93 f.].

After having outlined the requirements and requested functions of the assistance system in the procedure of technical system design, the development of a prototype is described in the following chapter.

4.2 System Design and Prototype

4.2.1 Development Methodology

The use of structured software development lifecycles helps to develop reliable software effectively. As the development of the prototype is a relatively short part in the scope of the project, within the methodical phases of implementation and validation (Figure 1), the waterfall model is applied as SDLC [23] for the technical proceeding. In order to meet challenges that cannot be foreseen during the requirement elicitation phase, iterations over the waterfall model are applied. They are based on – again – participative evaluations of the match of requirements and aim at adapting the technical system to the needs of prospective users. Further, these iterations can benefit to develop new social practices – for example, learning techniques or organizational innovations.

The waterfall model itself again consists of a staged process. The different stages and their goals are shown in Figure 3 and are covered by the following sections subsequently.

4.2.2 Requirement Elicitation Phase of the Waterfall Model

In this stage, technical demands were drawn from the results of the requirement analysis (catalogue of require-

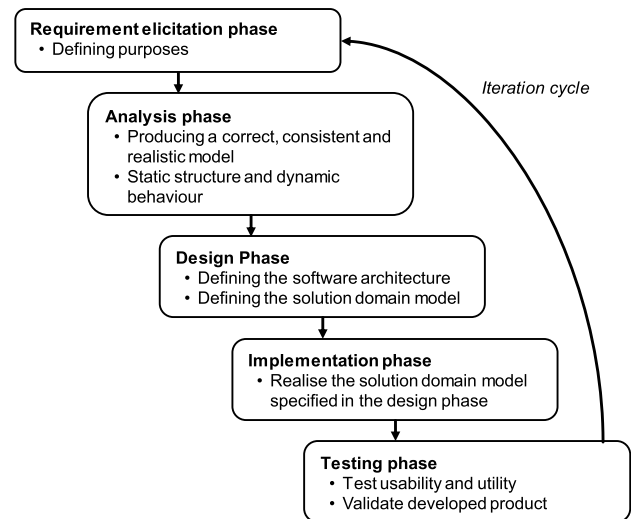


Figure 3: Waterfall model [23].

ment, chapter 3) and of the work process and work place analysis (chapter 4.1).

A first informal description of the required technical features and characteristics for the complete assistance system proposed a system which offers a mobile HMI (human machine interface) and delivers relevant information proactively. Further features were deduced from the aim to develop a prototype that can be tested easily in manufacturing enterprises. Therefore, the system needed to be flexible, inexpensive and straightforward to set-up. Thus, affordable commodity hardware had to be chosen, compatible to the concept of “Bring-Your-Own-Device”. The system furthermore was expected to identify which information is relevant to which user and deliver it accordingly in a proactive manner. With this feature, an important aspect of individualization requirements following the requirement catalogue (chapter 3) is addressed.

The system architecture is non-machine-specific and can be used with machines of different types and manufactures. It is extendible and supports adding functionality modularly. By this means, it can easily be adapted to user’s needs. Bearing in mind that a considerable part of workers in textile industry are so-called “digital immigrants”, which means that they didn’t grow up with digital technology, the setup and start-up routine of the system should be straightforward and easy to do for people with relatively little experience in information technology.

The prototype version described here was developed parallel in time to the work process analysis, which revealed a preference for a tablet as HMI on the part of the prospective users. Therefore, it is related to smart phones and smart watches as interface devices. Currently, it is

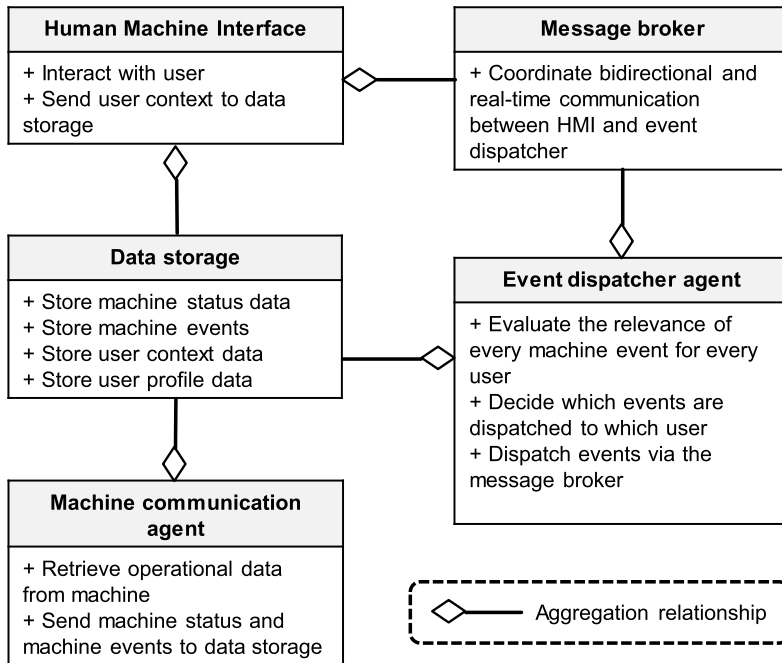


Figure 4: Static application domain model.

extended to a tablet version as requested by the future users in the weaving mills who participated in the analyses. In addition, the work process- and workplace-analysis yielded the need of a communication element complementing the assistance of the warp beam change process.

The formal requirements derived in this stage provided the foundation for the further development process and built the reference to validate the system in a subsequent phase. Concluding the formal requirement lists, the requirement elicitation phase is completed. The following stage in the waterfall model is the analysis phase.

4.2.3 Analysis Phase of the Waterfall Model

According to the waterfall model, the purpose of the analysis phase is to derive a consistent and verifiable model of the system. The model is referred to as the application domain model. The developed static application domain model for the prototype system is shown in Figure 4.

The static application domain model in Figure 4 displays all conceptual modules with their main purposes and their corresponding relationships. The hollow diamond at the one end of the connections between the concepts is the symbol for an aggregation relationship. Thus, two linked concepts can exist without each other as opposed to a composition relationship where they can only co-exist. The directions of the connections read for exam-

ple, in Figure 4: One human machine interface has the reference to one message broker.

As non-functional requirements for the back-end are modularity and extensibility, the goal is to decouple the single concepts as far as possible and use universal interfaces between them. This is manifested in the static application domain model outlined in Figure 4, as there is only aggregation; which means no composition relationships between the concepts. Thus, every concept continues to exist if others are removed. It enables removing, changing and adding concepts in a modular fashion.

4.3 Implementation in Laboratory

4.3.1 Design and Implementation Phase of the Waterfall Model

With the waterfall model in mind, the task of this phase is to design and implement the front-end, i.e., the part of the software that is visible to the user and with which the user can directly interact [24]. Therefore, it has to present data, push notifications to the user and allow the employment of further application modules in a usable and utile way. While utility describes the level of fulfilment of demanded features, being already evaluated in the conception phase, usability rather considers the ease of use of these features can be used [25]. The criteria of this re-

requested standard were drawn from the requirement catalogue (chapter 3), including DIN EN ISO 9241-11 [19] with its aspects effectiveness, efficiency, satisfaction and specified context of use, as well as from the work process and work place analysis (chapter 4.1). The technological design choices include a platform selection, hardware device choices, as well as software determination. Based on the idea of a smartphone as HMI at that time of the project course, the three existing smartphone platforms were evaluated with regard to project suitability. Aspects serving as evaluation criteria were market share (covering as many devices as possible), estimated investment costs, affordability of hardware, estimated time to market, development tools and ease of development. The comparison of the different smartphone platforms determined Android to be the application's operating platform. In between, the assistance system is realised on a "ThingWorx" platform which allows communication with a large scope of interfaces, independent of their own systems software, thus including Android based devices.

With the general specifications from the conception and the set of technological design choices serving as a framework, the next step was to focus on the design and implementation of the HMI application for the assistance system. This user interface includes several features which allow a thematic grouping into seven modules, namely modules for initialization, notification, events, machine status, data comparison, local database and smart watch extension. Further modules can be integrated if requested by the user on a case by case basis.

The so-designed early prototype was implemented in a laboratory situation and subjected to first user tests, following the last phase of the waterfall model. In Figure 1, this refers to the phase of systems building. From here, the further technological development and optimization is covered by several iterations of the waterfall model in the systems building and systems installation phases.

4.3.2 Testing Phase of the Waterfall Model

After explaining the concept of the assistance system in a brief, verbal summary, each user received the same introducing story describing the situation in which the first part of the test took place. The story portrayed the purpose of the test, specified and considered the context of use and helped the user immerse into a typical use case scenario with the following story line:

Imagine you work as an employee in the weaving department of a big textile manufacturer. As part of a six-man team per shift, your team's task is to ensure that the 100

weaving machines are working safely and with maximum productivity in order to keep up with the immense competitive pressure.

For a more efficient error correction, your employer introduced the presented mobile assistance system, which sends error and status messages in form of push notifications to your smartphone and possibly smartwatch. It shall guarantee that you are notified of machine problems in real-time, even, if they occur on the other side of the huge production hall.

Furthermore, the assistance system is 'context-sensitive' configurable. This means that you can subscribe to messages of particular machines that are of interest to you. If they are not of interest, you can also block them. For all other messages, the system determines by itself, which messages are relevant for your user profile.

Recently, two machines have caused various issues. Your shift leader has, therefore, decided to subscribe you to all machine events of the two faulty machines: The "Dornier A1" and "Picanol OMNIplus 800" weaving machines.

The second part of the user test took its cue from the cognitive walkthrough. The user had to perform a given task which he could accomplish by searching the interface for available actions, selecting the most appropriate action and then verifying its progress. The test participants were asked to explicitly name and comment on all their thoughts and actions while searching and clicking the interface and solving the tasks. This addressed the usability characteristic of providing a product that can be used in an effective and efficient manner.

The test guides who read out the tasks to the users took notes on all positive and negative findings. Furthermore, the user's comments were recorded to allow a retrospective analysis.

Next, in the user test, a use case scenario was simulated to test the application in a production environment. It should examine whether users were able to react to real and live machine notifications, which made the core element of the application. Testing the application in a real environment is essential since it stresses the specified context of use criteria as part of the usability.

Equipped with the smartphone application, the test user was positioned in the technical laboratory of ITA with the task to identify and name occurring machine errors. These errors were provoked through one of the test guides by pressing the emergency stop of a weaving machine.

When the particular notification arrived, the user first would notice the new machine notification, then open it and understand the information which provides him with information about the affected machine and the reason for

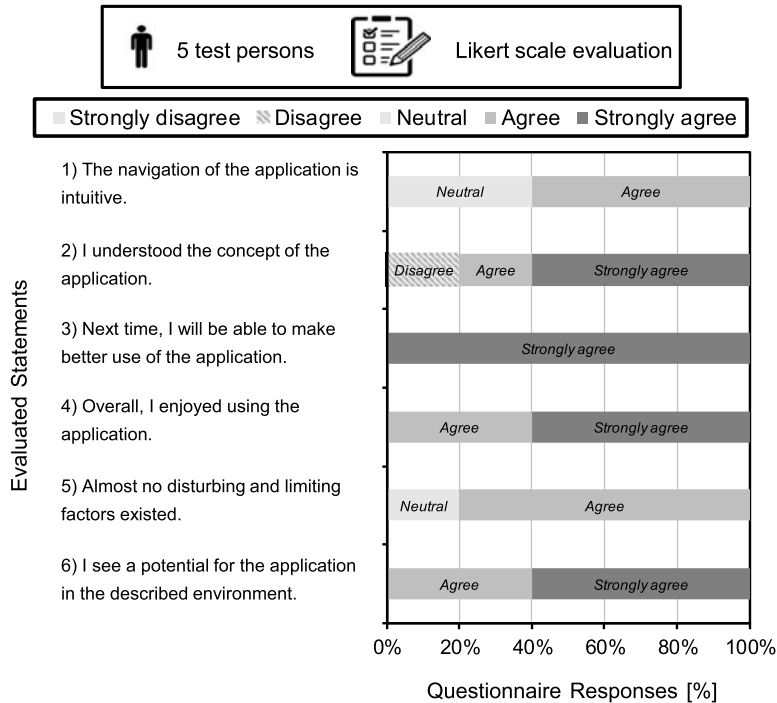


Figure 5: User test questionnaire responses.

the notifications. If the user could identify the correct error cause for the correct machine without any difficulty, the test was considered to be successful.

Asking the user to express his/her opinion extracts the more emotional-related level of satisfaction. In the last test part, the users therefore were asked to fill out a questionnaire. This aimed to extract explicit feedback after the users had been able to gain an overall impression of the application.

The questionnaire stated six short and precise statements in a closed manner to allow a comparable, quantitative analysis of the overall feedback [26]. These statements were graded by the users according to the Likert scale scheme. This scheme consists of a bivalent and symmetrical about a neutral middle scale on which the users expressed their attitude towards the statement ranging from “strongly disagree” (-2) to “strongly agree” (2) [26]. The statements are represented in Figure 5.

In addition, each statement provided a text field in which the users were asked to openly state reasons for the selected Likert grade. This allows a more in depth exploration of the wide range of positive and negative aspects arising from the issue [26].

The questionnaire completed the user test with the overall assessment of the application.

Concerning the test results, in general, the test participants followed a trial-and-error approach so that even

when a task could not be resolved at first try, they quickly recovered and found the correct actions. Only in a few cases the user appeared to be stuck. Though the implemented help option provides necessary answers and hints it was often forgotten about or simply not used. In order to address this issue, the help module must be improved. The current help option texts could be extended by illustrating images and animations and could be displayed more in the foreground instead being located in the options menu. Additionally, a guided tutorial showing at the very first start of the application could help the user become more familiar with the application and be more aware of the help function.

Simultaneously, the tutorial might explain the concept of the application, which did not become evident instantly to all users. The users especially showed comprehensive difficulties in regard to the distinction between notifications and events, the meaning of pressing the “Ok” button on notification cards, as well as the concept of the relevance rating.

Figure 5 displays the quantitative results of the questionnaire responses. It becomes evident that the application is perceived positively, as the majority agrees or even strongly agrees with the positive-phrased statements.

40% of the users agreed and 60% of the users strongly agreed that they enjoyed using the application (see Figure 5 (4)). This high level of satisfaction indicates a good

visual and functional system design leading to a high degree of usability. It also suggests that the identified drawbacks named below are of small magnitude otherwise they would influence the user's satisfaction in a graver manner.

In terms of intuitive handling (1), no negative feedback is given but a few small drawbacks hinder the users to learn the application's mechanics in a faster manner (see Figure 5). The same trend accounts for disturbing factors (5) which only consist of small and quickly fixable bugs that do not limit the functionality of the application but impact only slightly the user's satisfaction. In most cases, these bugs are, at the same time, the cause of the restrictions in regard to intuitive handling.

All test users stated that they will be able to make a much better use of the application in the future, as then they will be more familiar with it and do not require initial training time (see Figure 5 (3)). Additionally, all test users were able to name the simulated error messages successfully. Considering that the user test eventually consisted of a guided tour through the application it becomes apparent that the above-mentioned implementation of an initial tutorial could raise the user's learning curve.

The questionnaire's last statement asked if the user sees potential for the application in the tested production environment. 40% of the users agreed and 60% strongly agreed with this statement, indicating added value of the assistance system for the described environment of weaving mills.

5 Conclusion

As indicated in this report, the interdisciplinary research group introduced aims at the development and implementation of a digital assistance system for the attendance of modern weaving machines and connected technical devices in Industry 4.0 contexts. The assistance system is expected to increase productivity by supporting complex work procedures and to stimulate and accelerate learning processes. So far, a main result of the project is the development of a methodical approach integrating engineering methods (systems engineering, waterfall model) with methods from social sciences and education sciences. This integrated socio-technical perspective establishes both scientific and participatory input to the technical development and in turn feeds back the implications of the technical proceeding. Thus, we suggest that participatory elements should play an important and continuous role in the development and implementation of assistance system in general. In combination with a concept for qual-

ification and learning tools, this provides a sociotechnical approach for the design and implementation of digital assistance systems in industrial contexts. Consequently, the outlined interactions of technical and social aspects were translated into a research approach which links technical to social innovations.

As a result of our extensive work process- and workplace-analysis in weaving mills, the first stages of our project identified basic requirements and critical tasks, which are now supported by the assistance system. Central functional aspects derived from our analyses are the integration of machine data and maintenance clues in a homogenous application, a communication function and a platform for knowledge exchange and storage, and furthermore, the incorporation of learning-promoting tools for heterogeneous and diverse qualification and learning needs.

Relating requirements and critical tasks to suitable forms of assistance formed the base for developing possible assistance system concepts. A modular structure provides flexibility to adapt the system to further user's needs. Requested components were identified and a technological concept for the assistance system was selected. An evaluation of possible HCI concepts with regard to project suitability led to the decision for a preferred platform.

Additionally, a first test of the human machine interaction revealed that the test participants in general were able to deal with a given task employing the assistance system prototype and enjoyed working with the system. However, some drawbacks were detected and subsequently eliminated.

Altogether, our results indicate that an assistance system for the attendance of weaving machines as well as the organizational processes it is embedded in should be an appropriate support for both the critical tasks of the production process and the accompanied learning demands of a heterogeneous staff.

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References

- [1] Monostori L., Kadar B., Bauernhansl T., et al. Cyber-physical systems in manufacturing. In: CIRP Annals – Manufacturing Technology, 2016, 65(2), 621–641.
- [2] Saggiomo M., Gloy Y.-S., Gries T. Weaving Machine as Cyber-Physical Production System. Multi-Objective Self-Optimization of the Weaving Process. IEEE International

- Conference on Industrial Technology (ICIT 2016). Taipei, Taiwan, 14–17 March 2016.
- [3] Löhner M., Kerpen D., Lemm J., Saggiomo M., Gloy Y.-S. Intelligent assistance systems for industrial textile work environments. In: Simončič B.; Tomšič B. Gorjanc M., eds. 16th World Textile Conference AUTEX, 8th – 10th June 2016. Ljubljana, Slovenia, Faculty of Natural Sciences and Engineering, Department of Textiles, Graphic Arts and Design, 2016. File: 9-7 Mario_Löhner_full_AUTEX16.pdf.
 - [4] Bundesagentur für Arbeit (bfa). Der Arbeitsmarkt in Deutschland. Fachkräfteengpassanalyse. Nürnberg, bfa, Dezember 2014.
 - [5] Statistisches Bundesamt. Pressemitteilungen. 2017. Im Internet unter: https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2017/01/PD17_033_12411.html, Consulted on 02.02.2017.
 - [6] Zapf W. Über soziale Innovationen. In: Soziale Welt. 1989, 40, 170–183.
 - [7] Howaldt J., Schwarz M. Fit für Innovation – AK1 Innovationsprozesse managen. Stuttgart, Fraunhofer Verlag, 2011.
 - [8] Eggers T., Zettel C. »Soziale Innovation« im Fokus. Skizze eines gesellschaftstheoretisch inspirierten Forschungskonzepts. Bielefeld, transcript Verlag, 2000.
 - [9] Lichtenberg I., Altepost A., Bracke K. Organisations- und Qualifikationsentwicklung bei der Einführung Neuer Technologien. Köln, TÜV Rheinland, 1990.
 - [10] Lemm J., Löhner M., Dartsch N., et al. Erfolg durch Akzeptanz der Mitarbeiter – intelligente Assistenzsysteme in der Produktion am Beispiel der Textilindustrie. In: Weidner R., Redlich T., eds. Erste transdisziplinäre Konferenz zum Thema Technische Unterstützungssysteme, die Menschen wirklich wollen. Hamburg, Helmut-Schmidt-Universität, 2014.
 - [11] Defila R., Di Giulio A., Scheuermann M. Forschungsverbundmanagement. Handbuch für die Gestaltung inter- und transdisziplinärer Projekte. Zürich, vdf Hochschulverlag, 2006, 5–7.
 - [12] Haberfellner R., de Weck O., Fricke E., Vösser S. Systems Engineering - Grundlagen und Anwendung. Zürich, Orell Füssli Verlag AG (12th edition), 2012.
 - [13] Gloy Y.-S., Lemm J., Löhner M., Kerpen D., Ziesen N., Saggiomo M. Anforderungskatalog für Assistenzsysteme 4.0 an Textilmaschinen am Beispiel einer Webmaschine. Aachen, Shaker. Im Erscheinen.
 - [14] Karafillidis A., Weidner R. Grundlagen einer Theorie und Klassifikation technischer Unterstützung. In: Weidner R., Redlich T., Wulfsberg J.-P. eds. Technische Unterstützungssysteme. Berlin/Heidelberg, Springer Vieweg, 2015, 66–89.
 - [15] VDE. Assistenzsysteme/AAL. 2015. URL: <https://www.vde.com/de/dgbmt/arbeitsgebiete/aal>, Consulted on 09.02.2017.
 - [16] VDE. "Intelligente Assistenzsysteme für eine reife Gesellschaft". Positionspapier. Frankfurt/M, VDE, 2008.
 - [17] Löhner M., Lemm J., Kerpen D., Saggiomo M., Gloy Y.-S. Soziotechnische Assistenzsysteme für die Produktionsarbeit in der Textilbranche. In: Wischmann S., Hartmann E.-A., eds. Zukunft der Arbeit – Eine praxisnahe Betrachtung. Berlin, Springer Verlag, 2016.
 - [18] Saggiomo M., Löhner M., Lemm J., Kerpen D., Gloy Y.-S., Gries T. Influence of Human Factors on Cognitive Textile Production. In: Blaga M., ed. Proceedings / 15th AUTEX World Textile Conference 2015, June 10–12, Bukarest, Romania, "Gheorghe Asachi" Technical University of Iasi, Romania, Faculty of Textiles, Leather and Industrial Management, 2015.
 - [19] DIN EN ISO 9241-11. Ergonomische Anforderungen für Bürotätigkeiten mit Bildschirmgeräten – Anforderungen an die Gebrauchstauglichkeit. 1999.
 - [20] Lemm J., ed. Empirische Ergebnisse einer Arbeitsprozess- und Arbeitsplatzanalyse zur diversitätsgerechten Assistenzsystem-Entwicklung in der Textilbranche. Volume 1. In: Empirische Studien zur angewandten Technik- und Organisationssoziologie. Aachen, Shaker Verlag, 2016.
 - [21] Rohmert W., Landau K. Das arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse (AET). Handbuch. Stuttgart, Huber, 1979.
 - [22] Kuhlmann M. Beobachtungsinterview. In: Kühl S., Strodtholz P., Taffertshofer A. eds. Handbuch Methoden der Organisationsforschung. Quantitative und Qualitative Methoden. Wiesbaden, Springer VS, 2009, 78–99.
 - [23] Jeschke S. 2015. Advanced Software Engineering Aachen, RWTH Aachen University, Lecture notes, Kybernetik-Cluster IMA/ZLW & IfU in Aachen, Lehrstuhl für Informationsmanagement im Maschinenbau IMA, Zentrum für Lern- und Wissensmanagement ZLW, An- Institut für Unternehmenskybernetik e.V., 2015.
 - [24] WebFinance Inc. Front end application, 2016, URL: <http://www.businessdictionary.com/definition/front-end-application.html>, Consulted on 10.02.2017.
 - [25] Nielsen J. How Many Test Users in a Usability Study? 2012, URL: <https://www.nngroup.com/articles/how-many-test-users/>, consulted on 05.07.2016.
 - [26] Leung W.-C. How to design a questionnaire. Student BMJ. Volume 9. 2009, 187–189.

Bionotes



Andrea Altepost

Institut für Textiltechnik (ITA) der Rheinisch Westfälische Technische Hochschule Aachen University, Germany
andrea.altepost@ita.rwth-aachen.de



Mario Löhner

Institut für Textiltechnik (ITA) der Rheinisch Westfälische Technische Hochschule Aachen University, Germany
mario.loehner@ita.rwth-aachen.de



Nenja Ziesen
Institut für Soziologie (IfS) der Rheinisch
Westfälische Technische Hochschule
Aachen University, Germany
nziesen@soziologie.rwth-aachen.de



Daniel Houben
Institut für Soziologie (IfS) der Rheinisch
Westfälische Technische Hochschule
Aachen University, Germany
dhouben@soziologie.rwth-aachen.de



Marco Saggiomo
Institut für Textiltechnik (ITA) der Rheinisch
Westfälische Technische Hochschule
Aachen University, Germany
marco.saggiomo@ita.rwth-aachen.de



Yves-Simon Gloy
Institut für Textiltechnik (ITA) der Rheinisch
Westfälische Technische Hochschule
Aachen University, Germany
yves.gloy@ita.rwth-aachen.de



Niklas Strüver
Institut für Soziologie (IfS) der Rheinisch
Westfälische Technische Hochschule
Aachen University, Germany
nstruever@soziologie.rwth-aachen.de