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DESIGN AND IMPLEMENTATION OF A COLLABORATIVE SMARTWATCH APPLICATION SUPPORTING EMPLOYEES IN INDUSTRIAL WORKFLOWS

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Research paper

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Abstract

Due to new technological developments and the availability of affordable wearable devices like smartwatches, which recently hit the consumer market, employees in the corporate context can benefit from ubiquitous access to information. Especially in industrial production, there are complex and high involving workflows, which require the collaboration of multiple persons spread over different divisions. In such scenarios, fast and reliable communication is difficult and often disturbs work. Since smartwatches can be worn permanently on the body and the employee has non-disruptive access to information without the use of hands, such devices offer big potential for seamless support and guidance within a service system. In this paper, we identify a representative problem composed of a quality assurance process with practical relevance and design and implement an information system based on smartwatches in a design science approach. Since we infer meta-requirements for our system from the results of qualitative studies, the needs of employees are strongly considered and the developed software can be applied in a broad class of related problems. Finally, we evaluate the created meta-artifact in the identified scenario in order to obtain insights and knowledge about building information systems based on smartwatches for collaborative workflow support.

Keywords: smartwatch, industrial workflow, mobile information system, design science research, wearable computer, collaboration

1 Introduction

Due to new technological developments (Lasi et al., 2014) and the availability of affordable mobile devices during the progress of digitalization in the last decades, employees can benefit from ubiquitous access to information within the corporate context (Schmidt et al., 2015). New aspirations have been observed in recent years to improve industrial service systems and processes to gain a competitive advantage by the use of cyber-physical systems (Gorecky et al., 2014). In order to support employees in complex and high involving workflows, mobile information systems have to satisfy several requirements to yield more flexibility. Many dynamic processes in the industrial sector (e.g., production processes) necessitate that employees are neither restricted in their freedom of movement nor are occupied with hand-held devices like smartphones or tablets (Kortuem et al., 1999). In the last couple of years, the class of wearable computers emerged and entered the consumer market, which allows the users simultaneously to gain access to their digital workplace and to use their hands to interact in their work environment, e.g., utilizing tools or operating machines (Billinghurst and Starner, 1999). These properties are in particular met by smartwatches, which are permanently available, easily observable, unobtrusive, easy to use and carry along on the body allowing almost hands-free operation especially for receiving information (Ziegler et al., 2018) and thus have the potential to be used for mobile process support (Hobert and Schumann, 2017a).

However, scientific research focused little on the advantages of smartwatches supporting workflows. Since employees are an important economic factor, a collaborative and employee-centered approach can significantly increase economic success by reducing workload (Ziegler et al., 2014) keeping the system simple, as manual work is strenuous and has higher priority than interactive tasks (Boronowsky et al., 2001). Thus, the aim of our approach is to offer support and guidance for employees improving communication, time management and spent effort.

With the superordinate intend in this paper to understand how smartwatches can be deployed to support processes in the corporate context, a software artifact is developed, evaluated and discussed in order to address a problem originating from industrial practice. In this particular case, a service workflow composed of the interaction between machine operators and a quality assurance division is considered. The quality assurance division offers a company internal service to continually test currently produced parts for harmful deviations. For widely spread employees, fast and effective communication is difficult especially during manual tasks (e.g., repairing a machine). We provide and describe a socio-technical meta-artifact suited to target a broad class of related problems, which is then applied to the particular quality assurance scenario. Since the quality assurance is an integral part of the production, employees of both departments have to collaborate and digitalization of this service system (Beverungen et al., 2018) improves the value co-creation through direct ubiquitous communication and access to information. Beyond smartwatches in the consumer sector, this novel approach should illustrate the potential of smartwatches supporting workflows in the corporate domain, so far mostly unexplored in research. Furthermore, it should encourage entrepreneurs to use these findings in their companies and aside facilitate employees daily work.

In order to target this practice-orientated research problem within the industrial sector, we follow the design science research approach (March and Storey, 2008). We propose a research design strongly inspired by Peffers et al. (2007) including problem identification, deduction of objectives, design process, demonstration and finally evaluation to implement and evaluate an application for smartwatches. Thereby, we provide a level 1 design science contribution according to Gregor and Hevner (2013) by creating a situated implementation of an artifact for the introduced problem, provide the foundation for level 2 with a meta-artifact approach and address the following three research questions:

RQ1: How can smartwatches be utilized in industrial companies to support processes?
RQ2: How to design a software artifact supporting industrial workflows with smartwatches?
RQ3: How do employees evaluate the smartwatch application in the quality assurance scenario?

To answer these research questions, the remainder of this article is structured as follows: First, we present definitions of basic terms and outline related research and practice in section 2. Second, we describe our research method based on the design science research framework of Peffers et al. (2007) in section

3. By applying the framework to our problem domain, we illustrate the results of our design science approach in section 4. Finally, we discuss our findings and outline our research contributions for theory and practice in section 5.

2 Related Research and Practice

Smartwatches can be defined as a special form of wearable computer devices in the shape of digital watches equipped with various sensors and wireless interfaces (Cecchinato et al., 2018). As all wearable computers, they are worn on the users' body and are therefore always available to the users – independently of a specific location or time (Boronowsky et al., 2008; Rhodes, 1997). Due to the location on the users' wrist and the possibility to provide haptic feedback (e.g., vibrations), smartwatches can proactively demand the users' attention. Thus, they can immediately initiate interactions with users, e.g., when it receives an important notification. Technically, smartwatches are similar to mobile devices due to its hardware components. However, the use cases differ: wearable computers and especially smartwatches are usually limited to simple input and output options due to the small form factor (Malu and Findlater, 2015). Nevertheless, because of the fact that users are wearing the devices, they can always interact with them. In contrast, mobile computers offer more advanced input and output capabilities (Chaparro et al., 2015), but they can only be used when users get them out of their pockets and hold them in their hands.

Research on wearable computers started more than 50 years ago (Thorp, 1998; Rhodes, 1997). Whereas in the past most research contributions targeted technical aspects like constructing wearable hardware devices or extending its capabilities (Xiao et al., 2014), recent research focusses more on (1) designing software applications, (2) actual applications in private or business contexts as well as (3) the added value of wearable computers (Berkemeier et al., 2019; Hobert and Schumann, 2017b; Bieber et al., 2013). For instance, Lukowicz et al. (2007) stated that wearables can be used for information, guidance, and instructions in maintenance tasks. Aromaa et al. (2016) studied wearable and augmented reality technologies in industrial maintenance work and tested the usefulness for technicians. Zheng et al. (2015) elaborated a wearable solution to offer guidance to the user, to support hands-free operation and to enable collaboration with a remote expert in industrial maintenance. Furthermore, there are several contributions introducing concepts for the use of wearable computers mostly focused on maintenance (Witt et al., 2006; Nicolai et al., 2005).

Nevertheless, research on using smartwatches is limited. Only a few contributions exist that researched specific application scenarios in the business context. For example, Awan et al. (2018) use smartwatches for nurse documentation by voice recognition or Li et al. (2015) exploit smartwatch sensors to detect drowsiness of drivers. Villani et al. (2016) discuss the gestures interaction with smartwatches in situations where the touchscreen cannot be used, e.g., when wearing gloves or having greased fingers. Aehnelt and Urban (2014) provide a theoretical model for a systematic information transfer between assistance systems and worker. Ziegler et al. (2018) investigated smartwatches to support mobile industrial maintenance tasks as a complementary user interface. Schönig et al. (2018) presented a toolset for an IoT-aware business process execution system to integrate smartwatches as an internet of things device into a business process management system. However, this system lacks facilitating features for the employee as step-by-step workflow guidance and collaborative support.

Nevertheless, there exist many open research gaps, e.g., (1) application scenarios that are beneficial for enterprises are missing, (2) design knowledge is required to implement proper smartwatch applications and (3) usability aspects are unsolved. In many cases, only demonstration prototypes are produced and evaluated during experiments with participants lacking in practical experience.

Since the application of smartwatches is promising in the industrial context and offers multiple benefits for companies, there are already some commercial products available. *MeisterTask* (MeisterLabs GmbH, 2019) is a best practice web-based project and task management tool for teams providing desktop, tablet and smartphone interfaces enhanced with smartwatch compatibility. Besides the adoption of established mobile approaches, there are also smartwatch-centered products, which are directly designed for the device and an industrial scenario. The *Hipaax TaskWatch* (Hipaax LLC, 2018) is a corporation with *Samsung* and combines scenario fitting smartwatch devices with a construction kit for corresponding applications including gamification aspects (Deterding et al., 2011). *aucobo* (aucobo GmbH, 2019) offers interaction of workers and machines on the shop floor using a robust smartwatch equipped with a QR code scanner. *WORKERBASE* (WORKERBASE GmbH, 2019) is a rugged smartwatch specifically designed for industrial use (including a QR code scanner) combined with a platform for manual tasks which need to be completed on the shop floor. However, these products either lack of an adequate interaction in the smartwatch component, add more complexity for the employees, do not consider collaborative aspects, do not provide workflow support and guidance, have a limited range of functionality or do not provide any scientific background. These products are the first entries in this sector and are not widespread so far. Thus, a design science research approach can provide a theoretical and research-based foundation to consider the needs of companies and employees.

3 Research Design

To target the research gap outlined in section 1, we applied a mixed-methods approach based on the problem-centered design science research process model by Peffers et al. (2007) as shown in Figure 1. In terms of Iivari (2015), we utilize the inductive strategy to develop an artifact for a specific problem encountered in practice and then generalize it to address a class of problems.

According to the process model, the artifact development should be grounded in the problem identification phase (step 1). To this aim, we rely on the results of a series of workshops that we have conducted in summer 2017 within an industrial production facility. The main goal of these workshops was to identify application scenarios that are beneficial for both, the employees as well as the company. After discussing and evaluating the resulting application scenarios, we chose to focus on smartwatches to support manual working tasks in industrial workflows like quality assurance processes (see section 4.1). In order to get more detailed insights, we conducted additional focus interviews with domain experts involved in the selected scenario.

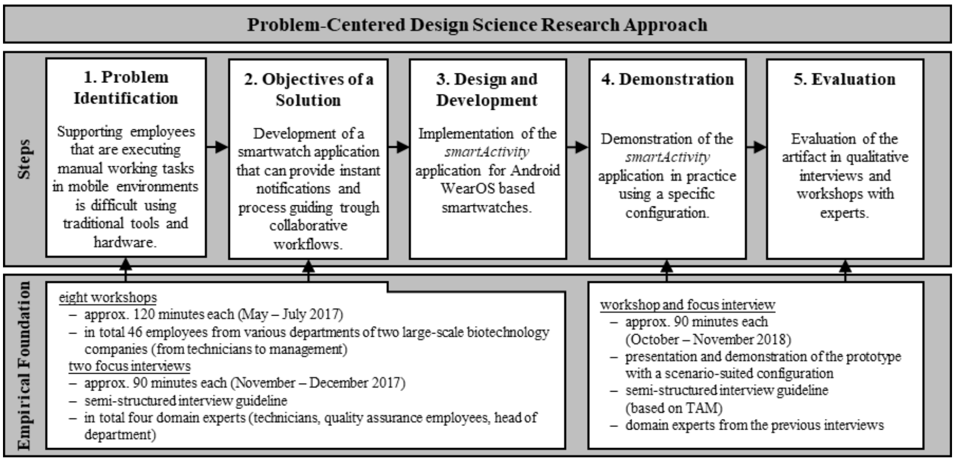

Figure 1. Research design adapted from (Peffers et al., 2007) with the empirical foundation.

With this quality assurance scenario as the identified real-world problem, we derived functional requirements as the objectives of our solution (step 2). For this purpose, we carefully analyzed the documentation of the workshop series and extended it with two focus interviews in November 2017. During these interviews, the questioned employees explained in detail how they are currently carrying out their work tasks and how they believe that smartwatches can support these workflows. Using this approach, we finally acquired nine meta-requirements that are the basis for the subsequent design cycle.

Following the design science research process model, we implemented a prototypical meta-artifact called *smartActivity* based on the deduced meta-requirements (step 3). By choosing an agile development approach, we were able to discuss intermediate prototypes regularly and improved them constantly until they met all mandatory functional meta-requirements.

Subsequently, we did a demonstration according to (Peffers et al., 2007) in step 4. For this, we have demonstrated *smartActivity* during a workshop and an interview including the presentation of a realistic configuration for the quality assurance application scenario in order to apply the meta-prototype.

Finally, we checked the suitability for the given use case in an evaluation by comparing the task characteristics of the application scenario with the developed artifact and analyzing the feedback of the conducted workshop and interview based on the Technology Acceptance Model (Davis et al., 1989).

4 smartActivity Application

In this section, we present the design of the *smartActivity* meta-artifact to support industrial workflows with smartwatches and to provide a solution that can be applied to address the quality assurance scenario.

4.1 Problem Identification

Consecutive to a workshop series targeting the capabilities of wearable computers in the industrial context, we identified a process within the daily work in production. The foundation of our examined problem is shaped by the interactions of employees within an industrial production and quality assurance workflow. Several workers are responsible for machines in a certain workshop, which are used to produce components for later assembled technical products. These are predominantly mills converting blocks of metallic raw material into complex structured elements. Each worker operates a group of machines, which have to be programmed, equipped and maintained. A crucial aspect is that the machines are located at different locations of the workshop. Due to the fact that the various milling-tools used in the automated machines wear out over time, the produced components can become inaccurate. In order to avoid assembly deficiencies, the components have to be checked and tested periodically by an employee of the quality assurance division.

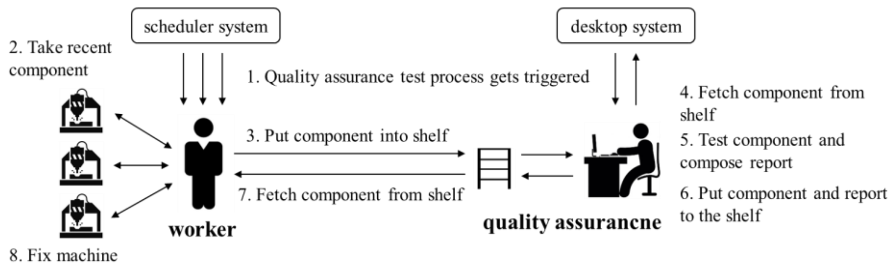

Figure 2. Current quality assurance workflow.

As shown in Figure 2, the service workflow is composed of several human-to-human and human-to-machine interactions. In the background, a scheduler system tracks and manages the pending quality assurance test jobs. These requests can also be triggered by persons or sensors. Once, a quality assurance test job of a certain component is due, the responsible worker takes a recently produced component from the desired machine. Next, the worker has to walk through the workshop and deliver the component to the quality assurance office. For this, the worker puts it on top of a destined shelf. Employees of the quality assurance division have to monitor periodically this shelf and successively handle every component which arrives. After completing the testing procedure according to the specifications, the component is put back into the shelf and a paper-based test report is attached. This report is composed manually in a desktop-based computer station and contains all relevant information. The worker at the machine can use this information to draw conclusions about the tool conditions. Finally, the worker has to check the shelf periodically and fetch all processed components. Under the directive of the report, the worker can fix the machines tools if required.

Apparently, this workflow offers the potential for improvement through digitalization due to two key problems. On the one hand, there is an uncertainty for all involved persons when a task of the counterpart is completed. Since, the workers move between the assigned machines and the shelf in order to periodically check whenever components are processed, long footpaths occur. Due to this fact, a machine with worn tools could produce a lot of inaccurate components until an already measured component is fetched from the shelf. This results in an unnecessary waste of time, raw material and money respectively. In addition, tardily or completely undiscovered variances can lead to some serious damage at the machine. On the other hand, there are media disruptions varying between digital, printed and written representations of the same information. First, an employee of the quality assurance division has to put the component id into the computer system. Then, the digital obtained protocol during the quality assurance test process is printed again and handed over to the worker who has to read and interpret it correctly. Merely, if the worker discovers any variances, the details can be checked at a desktop PC, which is mounted at the machine.

4.2 Objectives

Since in prior research, information systems including a smartwatch application for the industrial context are sparsely addressed in a collaborative employee-centered approach, we conducted qualitative interviews with several domain experts.

The primary idea was to digitally support the service system of production and quality assurance collaboration including human-human and human-machine interactions. The first functional requirement is to provide status reports of machines for the responsible worker. So far a traffic light system exists, which shows the state of the machine and particularly a red signal whenever an error occurs. The disadvantage of this system is that the workers are widely distributed within the workshop and they cannot see the signals all the time. Beyond, acoustical signals are a bad choice because the environment is very noisy. *"It is enough to indicate whether a malfunction exists at a particular machine or not"* (expert 1). In the case a malfunction appears, the responsible worker should be immediately and location-independently informed without interrupting work. Furthermore, *"workers in the vicinity should also be notified to intervene quickly if necessary"* (expert 1). For this, a group of workers has to be addressed simultaneously.

After the identification of the problem described above, the list of requirements extends. *"Machine downtimes can be avoided and the quality would raise if the worker gets notified whenever a components quality assurance test is concluded"* (expert 1). This implies a message *"component measurement done"* (expert 2). Once a message was received, the employees of the quality assurance division want to have small feedback like *"got the information"* (expert 2) to make sure that possible fatal malfunctions are treated. Some cases require an immediate stop of a machine otherwise *"100 % waste is produced"* (expert 2) in the meantime and a lot of money is dissipated. After a worker has received a notification and took care of the issue, the worker should *"easily wipe the notification away"* (expert 3) and indicate the concern as completed. On the other side at the quality assurance division, it should be possible to input test results. *"The measuring program could be designed in such a way that the data is automatically entered into the system, or by the employee operating the machine"* (expert 1). Since there is no interface, this remains a manual task and the relevant information has to be compiled by hand. To identify the quality assurance test job at least *"part number and machine number must also be included"* (expert 1). In order to provide a recommendation for action, a survey of quality assurance test results including characteristic numbers should be attached to the notification. *"Not all measurement data would have to be transmitted at all, one 'okay' is enough, if everything is within the bounds"* (expert 3). More precisely, it should be distinguished between *"alright and not alright"* (expert 2), and the worker can later take a look at the full report at the terminal located at the machine. Due to the small display and the limited capabilities of a smartwatch for displaying a lot of text *"relatively little information should be transmitted there"* (expert 2). To solve this, *"in the best case only the dimensions where deviations exist should be displayed"* (expert 2). For further improvements of the quality, there should be a statistic, which tracks the errors for each machine respectively to figure out *"how often which error occurs"* (expert 2).

Finally, there are several non-functional objectives, which refer to the used hardware or other legal regulations. Relating to the battery life of a smartwatch *"we have two shifts so the battery should last 24 hours"* (expert 1) but *"eight to nine hours is a real must because this is one shift"* (expert 2). A smartwatch should be used for a working shift without any interruption and can be charged afterward. In terms of robustness, *"the smartwatch including the wristband should be impact-, water-, oil- and acid-resistant since we are dealing with machines and aggressive liquids"* (expert 2). *"In addition, we need protection against electronic discharge in the assembly department"* (expert 1). The hardware of the smartwatch should offer several protections against environmental influences especially occurring in the industry. Since *"we do not need any employee-related information like a name or id"* (expert 1 and 2) and the tracking and processing of this information are not allowed in a lot of companies due to the European general data protection regulation, smartwatches are addressed by their respective related functional workplace.

We summarize all described requirements in Table 1, being the foundation of the next section where the requirements are generalized and implemented in our artifact.

Functional requirements			
worker	**FR_1**	Display alerts of machines	immediate and independent of location
	FR_2	Notifications of concluded QA jobs	
	FR_3	Acknowledgment of received notifications	
	FR_4	Display aggregated QA test reports	
QA	**FR_5**	Input of QA test reports	
	FR_6	Provide error statistics over time	

Non-functional requirements	
NFR_1	At least 8 hours of battery life
NFR_2	Protections against environmental influences (impact, water, oil, acid, and electronic discharge)
NFR_3	No acquisition of employee-related data

Table 1. Functional and non-functional requirements.

4.3 Design and Development

In order to meet these specified objectives, we designed and developed the software meta-artifact *smartActivity*. Since FR_1 – FR_4 necessitate the immediate and location-independent access to information, we deploy smartwatches in the mobile parts of the system in order to ensure seamless and uninterruptive use. We want to provide a solution, which can be applied in numerous situations and various scenarios. Thus, previously to the implementation, an abstraction step is done. This allows us to yield a more flexible approach, which is easily applicable and not overloaded. Therefore, we deduce meta-requirements based on the results of section 4.2 listed in Table 2.

Functional meta-requirements		
desktop backend	**FMR_1**	Manage devices
	FMR_2	Manage workstations
	FMR_3	Manage workflows
	FMR_4	Create activities
	FMR_5	Display and respond to tasks according to workflows
	FMR_6	Provide statistics
smartwatch	**FMR_7**	Receive task notifications hands-free
	FMR_8	Send immediate task acknowledgments
	FMR_9	Provide workflow guidance

Table 2. Functional meta-requirements.

In order to generalize the problem presented in section 4.1, we prescind the roles of workers and employees of the quality assurance department to mobile and stationary workspaces. Hence, all integrated devices are identified by workstations and can either use the mobile software component (e.g., smartwatches), the backend (e.g., desktop PC) or both (e.g., smartphones or tablets). Consequently, an administrative element has to manage devices and assign workstations to them. In addition, we want to design a meta-system beyond quality assurance processes and allow any kind of workflows. Thus, the administrative component can build workflows including underlying tasks. Using this workflow templates, the system can create activities which are an instance of a workflow and can guide employees through a collaborative process. A core requirement is to handle the dedicated tasks of an activity. Tasks are displayed and subsequent actions are generated and respectively triggered after the recent step is processed. In the case of the mobile software component, notifications of incoming tasks are released and an acknowledgment is sent once the notification is confirmed. Furthermore, the mobile component offers workflow guidance while reducing displayed information to the necessary and required inputs to a minimum due to small device displays. We present our overall system architecture in Figure 3.

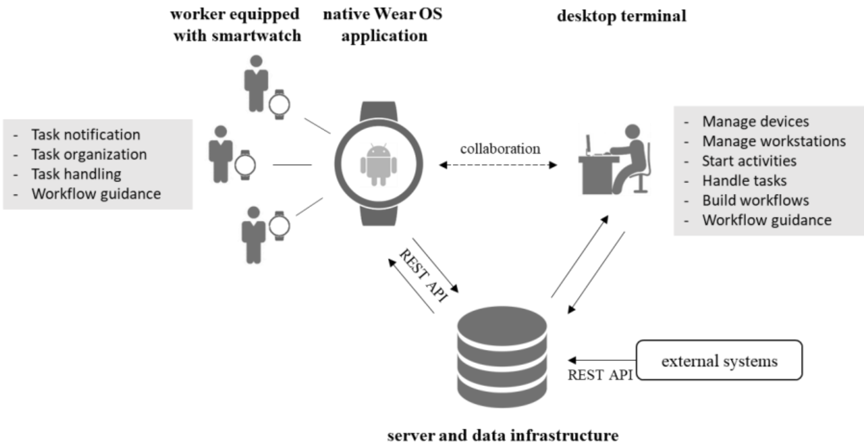

Figure 3. smartActivity system architecture.

There are three key components: (1) a native *Android Wear OS* based smartwatch application, (2) a web component, which can be operated using a browser on a desktop or mobile device, and (3) a server, which operates the whole system offering all interfaces and containing the database. An enterprise wireless network is used to connect all components in a fast, reliable and secure way. As confidential information like machine and workflow states are exchanged, no further online service is involved. Additionally, in this way, it is not possible for external devices to connect to the system and disturb the process. Furthermore, this infrastructure is more failure prone and does not depend on the availability and future compatibility of other services.

For the server component, we use PHP to benefit from its abilities related to web applications. In this way, the desktop terminal is empowered with modern web technologies like HTML5. The smartwatch application is integrated using a provided REST interface. In addition, this interface can be utilized to receive information from other systems like a scheduling system mentioned in section 4.1 or event triggering sensor data. For data storage, we choose a relational MySQL database. We selected well known and approved technical approaches at the server side, in order to ensure easy applicability in practice.

The web-based component is the backend of the *smartActivity* application and is displayed in a browser. It allows employees to manage and supervise all processes on a stationary device, like a desktop PC or mobile devices, like a tablet or a smartphone, which ensure an adequate overview with decent display size. In order to protect the system from unintentional access, it requires a login including a password. In general, *smartActivity* addresses workplaces (e.g., quality assurance employee) instead of persons with their respective names in order to protect them against observation and tracking. Once logged in, every user has an own dashboard containing all actual relevant information. For a quick overview, critical factors, like the occupied workstations, open activities, open tasks, and some statistical analytics are shown. Furthermore, a list of pending tasks is provided. A screenshot of the dashboard is given in Figure 4. In the first step, all mobile devices can be registered in the backend. In our case we just use smartwatches in the mobile domain, but because there is no technical limitation to smartwatches every device can be integrated. Besides, workstations can be managed (created, edited and deleted) including a name and a description. Once this is done, every workstation can be assigned to a previously connected device and can now be addressed by its workplace name.

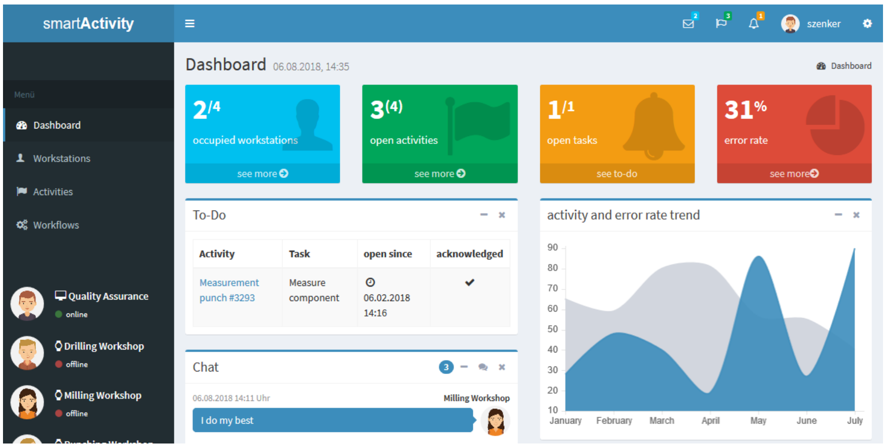

Figure 4. *Dashboard of the web-based component.*

The key functionality of *smartActivity* is to manage activities and their subordinated tasks. Our application provides two different ways to create activities. On the one hand, a custom activity using a name, description, first task, and the intended workplace can be defined. This enables full flexibility of the covered process. However, every successive task has to be customized with a name, description, and receiver accordingly, which is not reasonable due to the very limited capability of text input on smartwatches. On the other hand, an activity can follow a predefined workflow to guide an employee through all steps. In favor, our application provides a workflow editor where arbitrarily shaped workflows can be compiled. The workflow builder is shown in Figure 5.

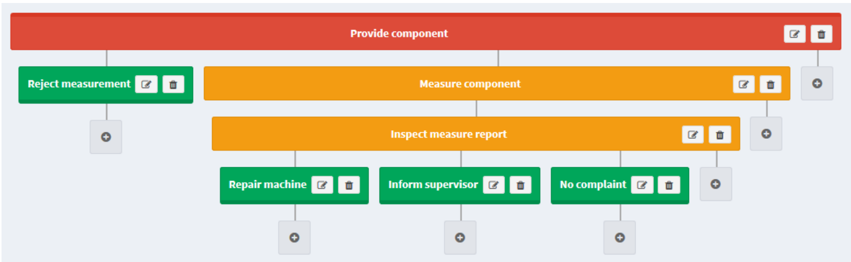

Figure 5. *Workflow builder showing a quality assurance scenario suited workflow.*

Successively, the steps within a workflow can be added, starting with a primal task (red) towards the final tasks (green). It is also possible to edit and remove steps. Furthermore, alternative flows can be implemented, which are indicated by multiple nodes in the same level of the tree. Workflows then are traversed from the top to the bottom and the employee can choose the adequate path respectively from one step to the next one. In Figure 5, a possible workflow for the scenario presented in section 4.1 is given. Once an activity according to this certain workflow is created, a “provide component” task is generated and sent to the selected workplace. Until a final task, e.g., “no complaint” is reached, the involved workstations are informed respectively.

The smartwatch application is the mobile component of *smartActivity*. It is built as a native *Android Wear OS* application since this operating system is the only commercially system that is used by multiple vendors and covers almost 40 % of the smartwatch market (Statista, 2019). In addition to the wide range of smartwatch models, it has the advantage that such an application can run on every wearable computer (e.g., smartglasses) with *Wear OS* and only the graphical interface has to be revised. In order to use the full potential of mobility, this is developed as a standalone application, which does not require any connected smartphone and is executed on the smartwatch itself (Google and Open Handset Alliance, 2018). The application consists of three major screens shown in Figure 6. Whenever the application is started on a smartwatch, it connects to the server and establishes communication calling the REST interface. For a newly connected device, it does the registration negotiation automatically in order to be assigned to a workplace. If the device is registered, it retrieves the relevant data from the server including the actual list of tasks. In the main menu of the smartwatch application, which can be accessed using a wiping gesture, the list of tasks, statistics, received messages and settings can be reached. As soon as a new task arrives, it is added to the task list and a notification appears (see Figure 6 (1)). The combination of the visual and tactile perception is used to ensure the attention of the employee who can either acknowledge or postpone the notification. The most active element is the list of activities (see Figure 6 (2)). Here an employee can quickly survey all tasks that are assigned to the workplace. In order to react on a task, it can be selected in the activity list with a tap and all the task details as activity name, name of the workstation involved in the previous workflow step, timestamps and all respective possible next steps are shown (see Figure 6 (3)). When the actual task is done, the employee can confirm it by selecting the next state in the process from respective options, which are automatically suggested regarding the defined workflow. Furthermore, the receiver of the next task is determined automatically. Apparently, the functionalities and the amount of displayed information on the smartwatch application compared to the desktop backend are strictly limited facilitating the usability of the application.

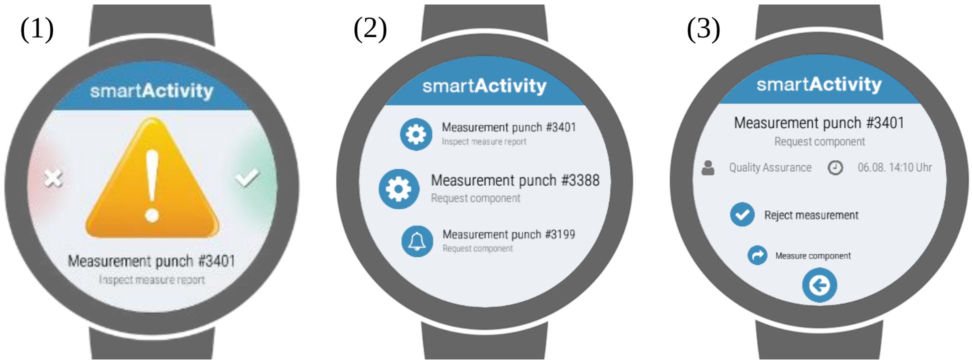

Figure 6. Screens of the meta-prototype, configured for the quality assurance scenario.

4.4 Demonstration

After we have presented the design of the *smartActivity* application, we demonstrated it to domain experts. For this, we conducted a workshop with experts within the industrial context. Since we did an abstraction step and designed the artifact for adoption in a broad application area providing much functionality, a crucial point is to show and highlight the relevance of the solution in practice. For this, we created a workflow that covers the collaboration process between workers operating machines and employees of the quality assurance division shown in Figure 5. Independently of the particular trigger (a scheduler system respectively a sensor using the REST interface or a human at the desktop backend), the activity starts with the task “provide component”, which appears on the worker’s smartwatch who is responsible for the desired machine and encourages him to deliver a recently produced component to the quality assurance office. The worker has the option to quit the process with “reject measurement” in senseless situations or to deliver the component and return the next task “measure component” to the employee of the quality assurance division. Since the system is able to handle acknowledgments and can postpone tasks, the employees of the quality assurance division can dispatch their requests as habitual. As soon as the particular component is measured and the report is gathered in the desktop system, the employee puts back the component to the shelf and notifies the worker with the “inspect measure report” task. In addition, all relevant information about the result can be attached so that the worker knows immediately whether there are disturbances or not. Furthermore, these aggregated values are used in the background to build error statistics over time. According to the transferred report, the worker can finish the workflow with “repair machine” or “inform supervisor” in the case of deviations or with “no complaint” otherwise. In this way the worker can save long and frequent footpaths, information flow is much faster and media disruptions are eliminated.

In this case, we find it reasonable to use smartwatches for the workers and the desktop backend for the quality assurance division. Workers require a mobile device since they have to move through the workshop, use their hands to operate the machines and it would be difficult to spend attention to handheld or other displays. They benefit from the direct visual and tactile notifications and the aggregation of quality assurance test results, which makes it easy to draw fast conclusions. As employees of the quality assurance division have to input and to deal with a lot of data, a desktop PC is a good choice at this side. Observing the acknowledgments, they can make sure that quality assurance test results are perceived especially in critical situations in which damage of a machine impends. Both collaboration parties are guided through the process according to the defined workflow and there are several decision options available for the different circumstances.

4.5 Evaluation

After we have demonstrated our solution to practitioners, we conducted a workshop and qualitative interviews to get feedback from experts. First, we want to discuss how the identified requirements are adapted to the presented artifact. Second, the results of the workshop and interviews are analyzed.

In the domain of functional requirements, all identified points are addressed. Alerts of machines (FR_1) can be displayed in such a way that a minimal workflow with two tasks “check machine alert” and “done” is defined and the triggering system calls the provided interface to populate the new activity including the responsible person. Consequently, we allow every source of activity creation which makes the system very flexible and easy to integrate into other system landscapes. As already shown in section 4.4, we implemented notifications for concluded quality assurance test jobs (FR_2). In general, notifications are shown whenever a new task of an activity appears in the task list. With the combination of visual and tactile stimulus, we make sure to get the attention of a person without interfering work. Through acknowledgments, every participating person is informed about whether the counterpart has perceived the notification or not (FR_3). The input of quality assurance test reports (FR_5) can be done in the desktop component where the data can be attached during the task creation process. In this way, it is possible to either display a green or a red notification indicator. Accessing this information at the detail page on the smartwatch makes it possible to inspect easily the aggregated quality assurance test report (FR_4). In the background, statistics are built using the logged data and overviews are created, which helps the employees to obtain insights for future organizational improvements (FR_6).

Since most non-functional requirements are hardware related and depend on the selected device, only NFR_3 is investigated here. *smartActivity* prohibits the tracking of person-related data. Devices are assigned to workplaces and hence the corresponding employee cannot be directly retraced. Furthermore, no information of hardware sensors like GPS positions, gesture recognition using the accelerometer or any chronometry is logged and analyzed. This ensures conformity with the European GDPR and improves the trust of employees in this new technology. We want to point out, that this mobile information system is user-centered and should lead to more assistance and flexibility in an employee’s daily work.

During the workshop and interviews, several positive, as well as some critical points, were discussed. As we have expected, due to the abstraction step of the requirements identified in section 4.2 and formulating meta requirements, the practitioners just use a small fraction of functionalities provided by the system. *“Now I see the possibilities that you actually have with such a system. Because with it I can theoretically control employees throughout the factory, distribute orders and so on”* (expert 4). In spite of the big extent, they gave the feedback that our solution fits their situation and improves recent vulnerabilities including media disruptions, unnecessary footpaths, and avoidable misproduction. Apart from competitive advantages through revised workflows for the company, mostly the employees benefit from such a system. Communication in relation to collaborative procedures is easy and fast using a device worn on their bodies. This reduces footpaths especially in considerable mobile fields of activity. It is important that the new system is uninterruptive, intuitive and does not add more complexity to the actual work to minimize the workload put on the employee.

Two main contributions are identified by the experts within our scenario. First, *“we expect several things using our recent scheduler system from our employees for years, but it is completely in the background as far as the employees like to use it. Now we bring it forward with a watch and make it more mandatory in a supporting and guiding way”* (expert 2). Casual processes and information systems gain more importance since they are integrated into a mobile workplace in a superior way. When these are perceived as useful, the full potential can be capitalized. Second, *“it is quite clear that quality is most* *important to us and with that system I definitely increase the quality"* (expert 2). Since quality leads to economic success, such a system is profitable for a company.

And yet, the requirements identified in section 4.2 are fulfilled. It is possible to exchange notifications between the stationary employees of the quality assurance department and the mobile workers in the workshop using smartwatches. Quality assurance test reports can be attached to give fast feedback. Acknowledgments of received notifications are advantageous: *"I visualize it to the quality assurance employee and he knows in case that the worker is currently busy, but it is being done later"* (expert 1). In terms of statistics, *"it would also help us. Then you can find out what you can do better"* (expert 2). In this way, team leaders can obtain insights about their machines. Through eliminating ineffective steps, workflows can also be improved. This results in several economic advantages. *"I can decrease through-put times with it"* (expert 2) and hence, *"deliver reliability because I have less downtime and perhaps less waste, less time I produce"* (expert 4). Also, the employee benefits *"I do not want my employees to run through the workshop but to receive information directly"* (expert 2). This was neither possible with a ring nor traffic light systems, because *"now you can transmit information"* (expert 1). *"The employee is more guided, which is exactly what I want"* (expert 4). And *"it is not so complex, it is easy to learn, especially for the young people who grew up with technical devices like that"* (expert 4).

The feedback also made us aware of some critical points. On a human level, there is a risk that *"an employee's freedom is cut"* (expert 4). Equipped with a system which is able to assign tasks to a person and *"there are little opportunities to disagree"* (expert 4), employees lose free decision about their acting. A corresponding question is *"who is allowed to assign tasks to whom at all"* (expert 4). In order to avoid conflicts at this level, it is very important, that such a system is used as support and guidance and not abused to extract the maximal output of an employee. A crucial point is *"to discuss systems like this with the employees in advance, what are the reasons and benefits"* (expert 1) and *"we do not want put pressure on the employees"* (expert 1). According to European GDPR, no personal data is collected and cannot be processed. *"It is not only data protection, but there are also practical reasons for this. We are interested in the machine and not in the person"* (expert 4). As well, it is not meant as a replacement for verbal exchange, so that *"the interpersonal communication falls by the wayside"* (expert 4). Alongside, organizational and technical properties are to be noted. *"There are a lot of different systems to be managed"* (expert 4) and *"the data maintenance must not be increased"* (expert 4) targeting complex interaction of many heterogeneous systems and redundant data storage in various formats. Another comment regarding the hardware is: *"I might have a problem with the size of the display, but I think it is a matter of habituation"* (expert 4).

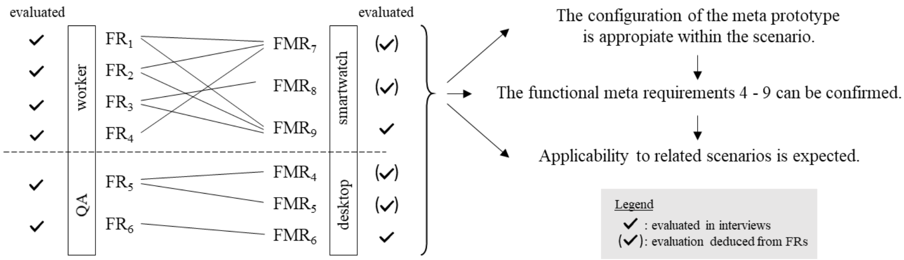

Figure 7. Relations of evaluated FRs and FMRs.

In summary, all experts found the presented prototype advantageous and deployable. *"I did not expect it to be so versatile at first"* (expert 4). So our software addresses the identified problems appropriately and offers much more possibilities for a company. *"I would even pay a lot of money for that because it is just important to be able to keep up with the competition"* (expert 2).

In Figure 7, we illustrate the relations of the FRs and FMRs. We have evaluated the functional requirements and showed that our prototype is appropriate within the given scenario. Since we can relate the deduced FMRs with the FMs, they can also be justified. Merely, FMR_1, FMR_2, and FMR_3 could not be directly confirmed, because they do not arise from the scenario and the background of the experts. These are technical prerequisites for the other FMRs and originated from abstraction and formalization.

5 Discussion and Conclusion

In this paper, we presented a mobile information system introducing smartwatches for the support of employees in collaborative workflows within the industrial sector. Inspired by the design science research method of Peffers et al. (2007), we illustrated a strictly problem-orientated research design. We first identified and described the problem found in practice through a workshop series (RQ1). We formulated objectives and inferred requirements based on qualitative interviews with practitioners. During the design phase, we developed functional meta requirements to address a broad range of similar problems. We presented the software meta-artifact *smartActivity* composed of a smartwatch application, a desktop backend and a server infrastructure (RQ2). With this, it is possible to cover the original problem of supporting a workflow within a service system including machine operators and a quality assurance division, where an exchange of information is slow, media distortions occur and employees have a lot of unnecessary footpaths. In a demonstration step, we presented our system to practitioners and explained the applicability with a suited configuration and workflow. Subsequently, we gathered feedback during a workshop and qualitative interviews for an evaluation (RQ3). According to the experts, the unique features of *smartActivity* result in an improvement of the process and product quality as well as in a reduction of the employees' workload. Particularly, the rigorous collaborative workflow guidance based on uninterruptive, immediate and location-independent information exchange was highlighted as a key feature and major contribution. Nevertheless, we also figured out some critical elements. It is very important that such a system is not to be used as a tool to put pressure on the employees or for surveillance but to offer support and guidance. In addition to the prototype, in practice, an authorization system for the desktop component is highly requested. It should be possible to assign different permissions to the levels in a company's hierarchy so that for example only a division leader can edit workflows. Another crucial factor is the deployed hardware. In the domain of smartwatches, handling is a big discussion due to the small display. Reducing the displayed information and interactive elements to the minimum necessary, this limitation can be circumvented. Industrial environments make tough demands on smartwatches. Today's devices offer adequate battery life and are often water- and dust-resistant. But the wristband is prone to acids and the display can get inoperable contaminated, e.g., with oil. For many industrial cases, the manufacturers have to improve the durability of their devices to make them fully convenient.

As with any practice-oriented research study some limitations exit: First, the empirical foundation of the developed meta-artifact is merely based on the quality assurance scenario. To address this limitation, we aim at transferring *smartActivity* to more use cases, though due to the paradigm of low-interaction, short-term and proactive use of smartwatches, there is a narrow field of application (Dvorak, 2007). However, we verified the utility of smartwatches in a service system of a quality assurance scenario. According to the interviews maintenance or support scenarios are promising. Employees who are widely dispersed over the company can at any time receive requests while using their hands for their proper work. Even non-collaborative workflows are possible, in which employees are just guided through a complex sequence of tasks and they can make sure not to miss any step. To cover these new use cases, specific requirements have to be met. Second, our evaluation is limited as the participants of the evaluation could only test the application for a short time-frame. Hence, we want to conduct a long-term evaluation in the future to get detailed insights into the impact of smartwatches on the employees' work.

Nevertheless, for practice we created an applicable software solution for many scenarios. We introduce new technologies to support employees in workflows. This helps companies to keep pace with the competition through consolidation of employees. Within the research domain, we created a level 1 design science contribution (Gregor and Hevner, 2013) in order to address the stated quality assurance scenario in practice. The presented meta-prototype forms the entry to a level 2 contribution, identifying design guidelines by extension, application, and evaluation to more use cases. The accumulated insights and knowledge can help to understand how to integrate smartwatches into the industrial context and how to design mobile information systems based on smartwatches to support employees in workflows. For a proper level 2 design science contribution including design principles, we need to traverse another design science cycle in order to generalize findings.

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