10.20378/irb-56111

Designing for the Factory: UX Prototyping for the Cleanroom

Roland Buchner, Verena Fuchsberger, Astrid Weiss, Manfred Tscheligi
Center for Human-Computer Interaction
University of Salzburg
Sigmund-Haffner Gasse 18, Austria
Firstname.lastname@sbg.ac.at

Abstract. In our work on facilitating human-computer interactions in the (smart) factory through contextual interfaces, we addressed the very specific user group of maintainers in a factory. Maintenance activities need to be flexible, quick, and cooperative, which, in turn, leads to specific challenges in research and designing interfaces for them. We present a case study that is based on a two-step user-experience prototyping process of a contextual inquiry and a participatory design workshop with actual maintainers and their co-workers (to include cooperative aspects). We identified the need to consolidate information originating from various interfaces and ubiquitous systems deployed throughout the factory in order to improve their workflow. On the other hand, design needs to facilitate awareness for broken and serviced equipment. To address these needs we developed a User Experience (UX) prototype that consists of a mobile interface for maintainers to enable tailored information presentation and situated displays intended to raise equipment awareness of broken equipment for co-workers in the cleanroom. In this position paper we discuss our approach and highlight the need to further research mobile interactions and situated displays in such a dynamic context.

1 Introduction

In the context of a semiconductor factory low production costs and reduced defect rates are essential for the success of a factory. The goal of such companies is to strive for a "zero-defect" production, as many of their products are used in safety critical contexts (e.g., automotive, aerospace). To reach this goal a rising number of factories these days is automated, however, humans still a play a crucial role in the production. Maintainers are among these important people as they are responsible to service the equipment in the cleanroom to guarantee a high quality production. To reach such high quality productions, research has already shown that by means of mobile interfaces (e.g., [3]) or situated interfaces (e.g., [6]) production processes in the factory could be improved. Regarding maintenance activities, the use of augmented interfaces in the factory context has shown promise and was researched thoroughly lately (e.g., [7]). However, most of the research only considered the single user in the factory, collaborative aspects have mainly been

overlooked. In our research of the semiconductor factory we found that cooperative aspects need to be considered as they affect the performance of how equipment is being serviced [4], e.g., to raise the sift leads' awareness of defective equipment. Research (e.g., [2], [8]) has shown that by providing the proper communication channels cooperation between maintainers in the factory could be improved. However, with our approach we do not only concentrate on a single user group (e.g., maintainers) we also want to keep fellow workers who are not maintainers (e.g., shift leads, operators) up-to-date of the equipment activities.

Furthermore, we identified pitfalls of interfaces in the factory, e.g., a lack of tailored information and limited acceptance of the deployed interface [4], which we also want to address in this paper.

Our approach is to develop experience prototypes that help to get a better understanding of the interaction experience as the cleanroom is a very difficult and complex context to research. They allow all stakeholders (e.g., maintainers, shift leads, operators) to gain first-hand experiences of the prototype's existing and future conditions by actively engaging with it [1]. In so doing, we present a case study where we describe a User Experience (UX) prototyping process that consists of a Contextual Inquiry (CI) [4] to develop an initial UX concept and a follow-up workshop with maintainers and co-workers to iterate and to discuss collaborative aspects (e.g., knowledge transfer) of the prototype. Based on the results of these two steps a UX prototype was developed that consists of a mobile interface in conjunction with situated displays. This combination supports different degrees of mobility and provides a smooth change of activities - from individual to collaborative ones, and from shared to public information and vice versa [5]. We aim at supporting personalized information presentation and information consolidation to reduce the information overload. By means of situated displays we want to visualize department specific information to reach a broader group of people to increase equipment awareness and to support cooperation between maintainers and co-workers (e.g., shift leads).

2 Contextual Analysis and Participatory Workshop

The **first** step was to gather the requirements and to understand the context, maintenance work routines, and maintenance tasks. Therefore, we (two researchers) conducted a Contextual Inquiry (CI) in the cleanroom of a semiconductor factory for three days and a two hours follow-up workshop with maintainers the fourth day [4]. The researchers gathered interview data using a dictaphone and handwritten notes. The interview data was transcribed

and qualitatively analyzed using NVivo[1] to better understand maintenance working procedures and processes. In the following we present findings of the CI that we categorized in three topics, namely: *interface usage, active information seeking and notification, and equipment handling*. These three topics were used as design rationale to conceptualize a first UX prototype.

Regarding *interface usage*, we identified about 15 different interfaces that are used by maintainers to complete their work. These interfaces often share the same or similar data, which create an information overload. The factory also has deployed terminals that run a central coordination interface throughout the factory that is considered to be a unified interface access to all different kinds of equipment items. Maintainers use it to check if other equipment items of interest are offline or to document their work. Their interface usage differs greatly and depends significantly on their working experience in the factory, and is furthermore historically influenced by their pre-experiences when new interfaces were deployed in the department.

Regarding *active information seeking* maintainers often look at terminals whenever they pass one to be up-to date on the equipment status. We also observed that maintainer got *notified* about the equipment by co-workers (e.g., shift leads, operators) or by the automated process control system.

Regarding the *equipment handling*, we found that the equipment is prioritized and assigned to specific maintainers at each shift change by the shift lead in their department. The rationale is that there are lot of different equipment types in the factory that are needed for the wafer production. Since the equipment is very complex maintainers are often specialized to only a specific type of equipment. If such prioritized equipment breaks then the responsible maintainer needs to check on it. During a shift cycle the priority of the equipment might change and therefore maintainers and co-workers need to be aware of such changes.

To develop a system that supports maintenance, the information needs to be tailored for maintainers and co-workers to reduce the amount of information. To improve the knowledge transfer and equipment coordination the equipment priority and maintenance activities need to be transparent and accessible to a greater group of people in the cleanroom. Based on the CI an initial concept for a mobile interface was developed, which displays personalized information, and a situated display to present equipment information department wise.

---

1 NVivo is a software for qualitative data analysis

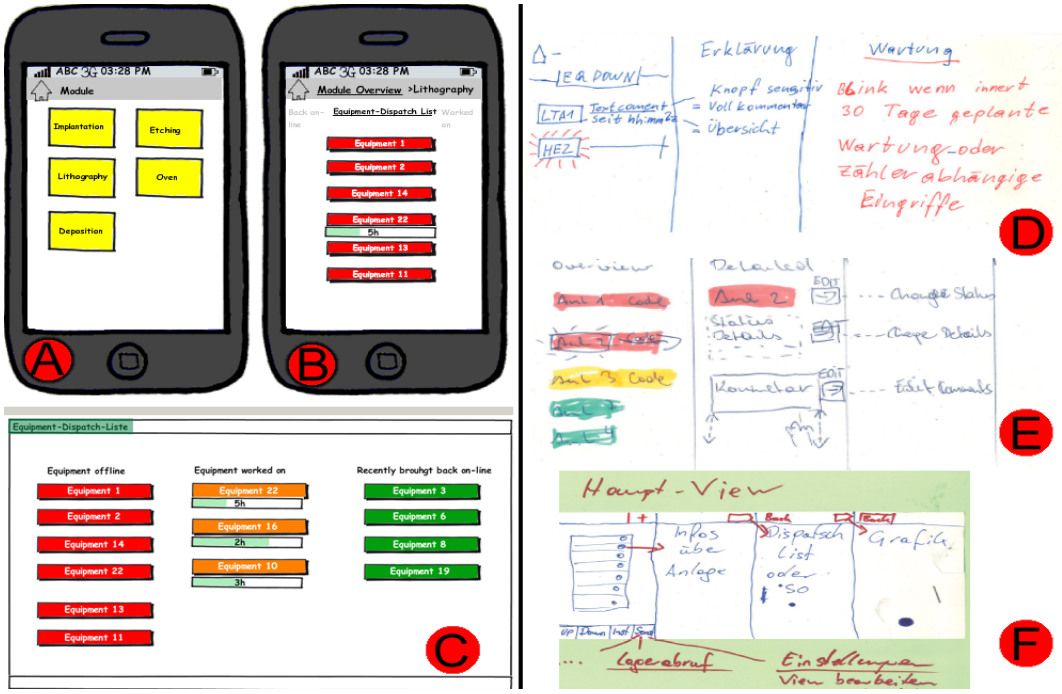

Figure 1. The letters A, B, C show the initial concept based on the results of the CI that was presented in the workshop. The letters D, E, F show images from the prototypes that were drawn in the workshop by the participants.

In the **second** step we conducted a participatory design workshop were we presented and discussed the initial UX concept (see Figure 1 A-C). The ideas consisted of a graphical and a scenario-based description of the mobile interface and the situated display - the former showing how personalized information could be displayed and the latter showing equipment related information to foster cooperation. The goal of the workshop was to discuss the relevance of information that needs to be displayed on the mobile interface and on the situated display. After the presentation the participants were asked to write down key words concerning what they thought was important for a maintenance tool and briefly explained their ideas. Afterwards, the key words were grouped and attached onto a wall. For example, in the discussion of the initial concept with the participants it became clear that a progress bar was not wanted (see Figure 1 B and C). It was stated by the participants that time predictions for maintainers were too difficult, even for the very experienced ones, and maintainers would feel being monitored during work. A missing information in the initial concept, which the participants claimed as important, was the information of who did changes to the equipment (e.g., who changed the priority of an equipment item), which was added later in the finial concept. After the presentation and the discussion the participants were asked to work in groups of two to develop paper prototypes based on their knowledge and experience in the maintenance area. To give them an idea of what prototyping

is, we briefly showed them what paper prototypes could look like, and we encouraged the participants to create their own paper prototypes (see Figure 1 D-F). Based on the outcome of the workshop the initial concept was iterated and an interactive User Experience (UX) prototype was developed, which is presented in detail in the next section.

3 The User Experience Prototype

The context of the semiconductor factory poses several challenges for contextual research. The cleanroom is an almost dust-free area with a 24/7/365 production cycle where the workers have to wear full body suits to reduce particle pollution. These challenges make it difficult to develop and to evaluate novel systems for this context, as the production must not be affected. That is why we chose to develop experience prototypes as they help "to understand, explore or communicate what it might be like to engage with the space or system" [1].

Our UX prototype consists of a mobile interface in conjunction with situated displays that are intended to support the maintenance workflow and to improve the transparency between different actors in the factory. The prototype addresses three aspects that we consider as relevant: reduction of the information, presentation of personalized equipment information, as well as fostering cooperation and support equipment coordination.

An overview of the prototype is given in Figure 2, which shows the screens of the mobile interface (A-D) and the situated display (E). To address the issue of information overload, different equipment states (offline, at work, on hold) are presented on the mobile interface as tabs as a first layer of information reduction.

Figure 2 A shows the default screen of all the equipment that is of importance for the maintainer. This is a personalized list, where the maintainer can add or remove equipment items. The screens B to D show only a subset of information that is available on screen A. Screen B shows equipment that needs to be serviced (defective equipment or where the service on the equipment is due) colored in red. For defective equipment the maintainer needs to know who is responsible and who set the priority. In screen C the equipment that is being worked on (equipment that is cleaned, serviced or repaired) is colored in yellow. Here, the maintainer knows who is working on the equipment and since when.

Screen D shows the equipment that is set on hold colored in grey (e.g., a broken part needs to be ordered from another company). Equipment that is colored in green is in a working state (actually processing or waiting for

wafers to process) and is only visible in screen A. To reach a high productivity it is important that the time the equipment is offline is as short as possible. However, depending on how many equipment items are offline, there might not be enough maintainers to work on all offline items, therefore the equipment is being prioritized, thus, maintainers need to know the equipment priority. To visualize the priority each tab lists the equipment from top (most important) to bottom (least important). The information on the equipment that needs to be visible at a glance is: the exact point in time of the equipment state change (e.g., online to offline), upcoming or current events, who set the priority or changed the equipment state, who is the responsible maintainer, and who is working on the equipment. The mobile interface provides maintainers with up-to date information of "their" equipment. They do not need to check on terminals all the time when they pass one to be up-to date on the equipment.

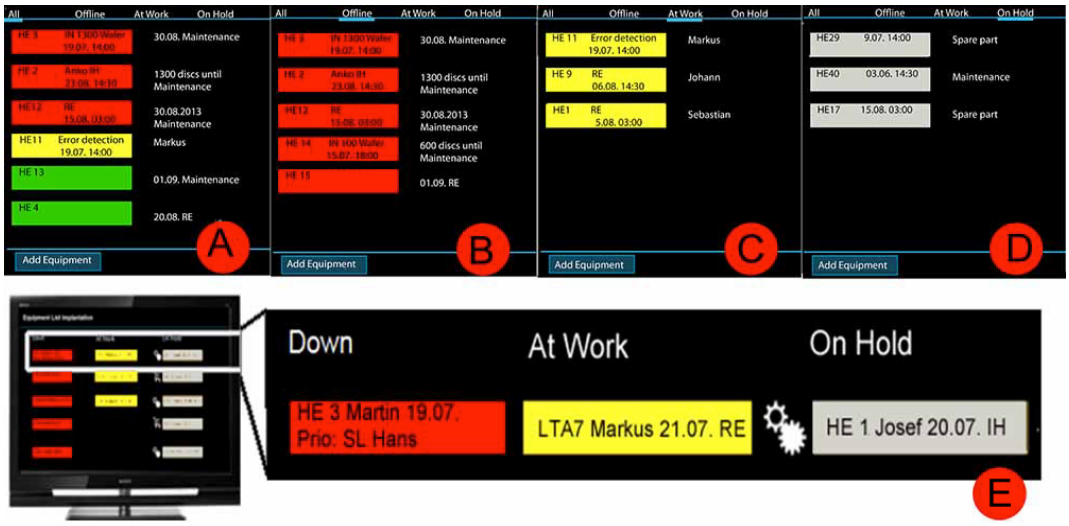

Figure 2. The mobile interface (A-D) and the situated display (E) after the CI and the workshop

The situated display was developed (see Figure 2 E) with the purpose to present information on defective equipment, equipment that is being worked on, and equipment that is on hold, in an intuitive and comprehensible way for shift leads, operators, and fellow maintainers. In contrast to the mobile interface the situated display does not show personalized information – the information is department specific and not responsive to user input, but with the same degree of detail. An additional information that is not shown on the mobile interface is the icon next to the on-hold state, which represents what needs to be done here (e.g., gearwheels indicate a cleaning or maintenance task). Due to the abstracted information visualisation of the situated display in comparison to the central coordination interface workers only get the

information of the equipment that needs to be serviced or is being serviced. As all workers in the cleanroom need to have a high productivity it is in their interest that the equipment is online and ready to process, therefore it is important to know its actual state at a glance.

4 Conclusion

In this paper we presented a case study of how findings from a user experience (UX) prototyping process in the challenging context of a semiconductor factory informed the development of a UX prototype (a combination of mobile interfaces with situated displays) to support maintenance activities and cooperation between co-workers in the cleanroom. The access to the cleanroom is very restricted and regulated with strict rules (e.g., no running, mobile phones need to be put in plastic bags) as the production of wafers is very sensitive and must not be disturbed by anyone. However, by means of a contextual inquiry (CI) [4] to gather requirements and the participatory workshop with actual maintainers we were able to carry out a UX prototyping process in such a challenging context in a feasible and fruitful way. The CI proved to be a reliable method to get an understanding of maintenance work in the factory, building the basis for the initial UX prototype concept. The workshop also showed its value as different participants got to know different opinions and interests when it comes to maintenance. Based on the workshop results the UX concept was iterated. However, to study user experience and cooperative aspects of the prototype, we need to explore a prototypical implementation of the system in the semiconductor factory in comparison with actual factory on-site solutions in order to continuously advance human-computer interactions in smart factories in various ways.

Acknowledgements

The Financial support by the Federal Ministry of Economy, Family and Youth and the National Foundation for Research, Technology and Development is gratefully acknowledged (Christian Doppler Laboratory for “Contextual Interfaces”).

References

[1] Buchenau M., Suri JF. Experience prototyping. DIS ’00, ACM, NY, USA, 424–433,

[2] Fallman, D. Wear, point, and tilt: designing support for mobile service and maintenance in industrial settings. In: DIS' 02
[3] Gehring, S., Löchtefeld, M., Schöning, J., Gorecky, D., Stephan, P., Krüger, A., Rohs, M. Mobile product customization. In: CHI EA '10
[4] Kluckner, P.M., Buchner, R., Weiss, A., Tscheligi, M. Collaborative reporting tools: An analysis of maintenance activities in a semiconductor factory. In: CTS 2013 . pp. 508–515
[5] Luff P. and Heath C. Mobility in collaboration. In *Proc. of* CSCW '98. ACM, New York, USA, 305-314
[6] Meschtscherjakov A, Kluckner P, Pöhr F, Reitberger W, Weiss A, Tscheligi M, Hohenwarter K, Oswald P. Ambient persuasion in the factory: The case of the operator guide. In: Advanced Semiconductor Manufacturing. 2011.
[7] Vartiainen, E., Boberg, P., Qvarnstrom, O., Brönmark, J. Applying augmented reality to industrial settings. In: Proc of the 4th Augmented Human Int. Conf. pp. 244–244. New York, NY, USA (2013)
[8] Väätajä, H., Janhunen, J. Supporting mobile maintenance work - needs and requirements. In: Industrial session at NordiCHI2012, Copenhagen (2012)