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MASTER THESIS

Theory of User Experience Best Practices in Software Product Lines

Submitted on 5. Sept. 2016

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Erlangen, 5. Sept. 2016

Abstract

This paper presents the theory of User Experience (UX) best practices in software product lines. The methodology used to derive the best practices is case study research, which has been applied to two independent software product lines within Siemens AG, the German engineering company. The resulting theory is based on Qualitative Data Analysis and other methods employed within case study research. The proposed theory is presented in the form of best practice patterns regarding the following three categories: UX creation, UX implementation and UX management in software product lines. The resulting patterns are designed to be used as a best practice handbook that can be applied by software product lines dealing with UX-related challenges.

Keywords

User Experience (UX), usability, human-computer interaction (HCI), software product lines, case study, best practice

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1 Introduction

1.1 Original Thesis Goals

The original goal of this exploratory case study was to answer the following research question: “What are the best practices employed by software product lines dealing with UX?”

The potential answer to this question was to be derived from the case study of three independent software product lines and their UX-related practices.

Initially the research goal was to achieve the following milestones during 6 months:

- Step 1: Formulate the research question
- Step 2: Realize the related literature review related to the research question
- Step 3: Choose the cases of software product lines, plan and prepare the case study
- Step 4: Realize the pilot case study research, collect the data
- Step 5: Analyze the data using Qualitative Data Analysis tools
- Step 6: Derive initial best practices based on the first case and get feedback on them
- Step 7: Adjust the case study plan based on the experience with the first case
- Step 8: Realize the second and third case studies, collect data
- Step 9: Analyze the new data using Qualitative Data Analysis tools
- Step 10: Integrate the analysis of all three case studies and derive the resulting universal best practices
- Step 11: Present the best practices in the form of patterns with references to the data
- Step 12: Present the result of the theory to the stakeholders including to the interested case study participants

The methodology of case study research was chosen based on the limited literature on the topic and thus the need of the exploration of the new insights and practices actually used in the industry, while dealing with the UX in software product lines. On one hand, the resulting theory was believed to have academic value, as it would contribute to the relatively underdeveloped UX research, especially with the focus on software product lines. On the other hand, the industry representatives, such as the case study participants from Siemens AG, had expressed their interest in the research and the resulting best practices, because it would help them store and transfer their knowledge regarding the UX. Therefore, the goal of the research was to meet both the academic and industry expectations by producing easily applicable and academically valid best practices.

In terms of the application of the research methodology, the goal was to establish a linear but iterative process of planning the pilot case study, realizing it, collecting the resulting data, analyzing the results, adjusting the planning and preparation based on the pilot case study experience, and then iterating the same steps for the next case studies.

The goal of the research result presentation was to produce concise and well-supported best practices using patterns to improve the applicability of the results.

1.2 Changes to Thesis Goals

The only change to the thesis goals was the realization of two case studies, instead of the initially planned three. This was mainly because of the time constraints and the more time needed to work on the first two cases than initially planned.

2 Research Chapter

2.1 Introduction

Over the last decade, 'User Experience' (UX) became a buzzword in the field of human - computer interaction (HCI) and interaction design (Hassenzahl & Tractinsky, 2006). Over time more and more companies realize the importance of the UX, as well as the importance of the UX research. The reason for this tendency is the changing approach to the products and services that goes beyond the functional aspects. While the functional aspects of a product have always been in the center of attention, the current trend is to also focus on the often overlooked aspect of User Experience – how the product works, which can arguably make the difference between successful and unsuccessful products (Garrett, 2010).

To define UX, in this paper we follow Hassenzahl et al. 2006 and go beyond the instrumental or functional level of UX:

“UX is about technology that fulfils more than just instrumental needs in a way that acknowledges its use as a subjective, situated, complex and dynamic encounter.”

To define a software product line, in this paper we follow the definition coined by Software Engineering Institute at Carnegie Mellon University:

“A software product line (SPL) is a set of software-intensive systems that share a common, managed set of features satisfying the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way.”

Recognizing the growing role of UX in software product line, our case study partners at Siemens emphasized the importance of a separate UX department within the software product line. At the same time, the literature review yields very limited results in the specific field of the UX in software product lines. A case study partner at Siemens also mentioned that the UX is not well studied for software product lines, because the current UX research is focused on websites and is not always applicable to software product lines. UX is currently a highly demanded topic in software industry as indicated by our case study partners at Siemens. This research uses this opportunity to apply the UX research to the context of software product lines in order to derive the best practices based on the case studies.

The main research question of the paper is: “What are the best practices employed by software product lines while dealing with User Experience?”

The paper focuses on the specifics of the User Experience in software product lines. The theory presented in the Research Results section is derived from the exploratory case study research. This methodology was chosen in order to discover and present, in a structured way, the UX-related best practices that are currently used in software product lines. Furthermore, qualitative data analysis tools are employed in order to analyze the collected case data and to synthesize the best practices from different case studies.

The paper is structured as follows. In section 2.2 we reviewed the related work, which has been used to compare and contrast various statements from the literature with the findings of the current research. In section 2.3 we briefly present the research question. In section 2.4 we present the research approach and methodology including case study preparation, case context, data collection, analysis methods and quality assurance. In section 2.5 the research findings are presented in the form of best practice patterns in three categories: UX creation, UX implementation and UX management. Finally, section 2.6 discusses the limitations of the results and the conclusions.

2.2 Related Work

User Experience in software product lines has not been particularly studied in academic community, according to our literature review. Therefore, this related work section concentrates on UX in general with the goal to derive product-line-specific aspects during the actual case study. The study of the related work draws the connection between the UX-related literature and the findings of this paper.

UX does not have a commonly acceptable scientific definition, because this is an evolving concept in academic literature. Its roots come from the broader concept of Human-Computer Interaction (HCI) and usability research. Two decades ago, given the limited computing capacities, the HCI was limited in its functionality and the main focus was on enriching the instructions and the usability, rather than the User Experience (Alben, 1996). In support of this statement, our case study partner at Siemens emphasized that their product line started the integration of its products into one system with centralized and common UX about ten years ago. Ever since the focus on the UX has only grown, which can be induced from the creation of separate teams responsible for the UX aspects of software in the studied Siemens product lines. Our study finds that product lines currently have a designated team responsible for product management, which includes the functional requirements of software – the classical HMI components, and another team responsible exclusively for the UX design.

Along with the industry adaptation of UX, conceptual papers emerged trying to establish shared understanding of UX, its characteristics and research basis. As there is no commonly accepted framework for UX study in software product lines, this paper categorizes the UX-related best practices into the following categories: UX creation or design, UX implementation and UX management.

Furthermore, there is a need for empirical research in order to realize rigorous studies on the subject of UX (Hassenzahl et al., 2006). Our paper also aims at realizing empirical UX research using case study research methodology.

While the academic community is trying to develop the conceptual framework of studying UX and empirical methods of research, the industry continues to develop and broaden the concept of UX going beyond the usability aspects in HCI, and including aspects like aesthetics, quality of experience, emotional impact, experience context and form etc. Interactions in particular have been a central UX topic recently (Hartson et al., 2012) and my research focuses on interactions as a key part of the UX. Such interactions are the basis for the best practices in our findings related to the evaluation of the UX prototypes by the clients, as well as the user training-related best practices.

Other researchers also highlight some characteristics of UX that go beyond the instrumental functionality. According to Gaver et al. (2000), diversion and intimacy are important aspects of User Experience design. My case study supported this position, which led to the inclusion of best practices centered on intimacy in terms of simple and direct interaction (but less on diversion). The importance of intimacy and intuitiveness as a UX component can be illustrated through the example of Gustbowl. Gustbowl is a communication tool, which consists of similar bowls in different locations (e.g. houses). Once someone puts an object into the bowl in one location, the bowl in the other location makes a dropping sound, which is to be an intimate and intuitive way of reminding the owners of the bowls about each other through non-verbal communication (van der Hoog et al. 2004). In contrast to this example, our case study finds that in software product lines the intuitiveness of UX does not always play an important role. Moreover, the head of the UX team in one of the Siemens product lines mentioned: “The intuitiveness is not the most important thing”, talking about the need of the UX training for the clients of their complex systems.

Beauty and aesthetics are among other non-functional characteristics that enrich the User Experience (Hassenzahl 2004). My research also contradicts this statement, as the aesthetics has not been mentioned as a key UX component by any of our case study partners at Siemens. Aesthetics seem of high priority at first sight, but the practitioners do not perceive it as a primary valuable UX component.

Another important aspect of User Experience in software product lines is its economic valuation by the company. According to some of our case study partners, the UX components are measured by their economic value before inclusion into the software. Such economic valuation can be realized by raking various UX components based on their perceived value to the user. (Sheldon et al. 2001). Our findings confirm this statement, while adding the additional valuation parameter – the development effort and risk of the given UX component. This is expressed in a best-practice suggesting the use of effort-value mapping for UX requirements.

Emotional aspects of UX are considered to be its integral part. Several authors argue that future HCI has to consider emotional aspects like stimulation, identification and evocation as part of UX (Logan et al., 1994, Hassenzahl, 2005). The emotional state of the user is hard to research because the rigorous research methodologies (such as study of brain responses to different experiences) is complex. However, there are attempts to develop more accessible, yet rigorous methods of evaluating digital user interfaces (UI), which are part of the UX (Longo et al. 2011). My research results indicate that evaluation of the UI is an essential part of the UX implementation process, however the advanced methodologies, such as evaluation of brain responses, are not widely used for software product lines. Instead customer evaluation of the UI and UX, as well as usability tests are the main evaluation techniques according to our partners (a software architect and a product line manager) at Siemens.

This concludes the core literature review about UX, its main components and possible implications in my research. However, some findings of this research go beyond the best practices related to the literature review, because some aspect of UX have not yet been extensively research and documented in the academic literature.

2.3 Research Question

The main research question of the paper is:

“What are the best practices employed by software product lines while dealing with User Experience?”

As the paper attempts exploratory case study research, there is no preset hypothesis. Instead the goal is the elicitation of the UX best practices in the following categories:

- UX creation or design best practices,
- UX implementation best practices,
- UX management best practices.

In an attempt to answer the research question, our theory presents a number of patterns that synthesize all the significant best practices into abstract and universal guidelines for any software product line.

2.4 Research Approach and Methodology

2.4.1 Case Study Methodology

This paper follows case study research methodology applied to two independent product line cases within Siemens. To realize the case study research, we used the methodology developed

by Yin (2013). That included preparing for the case studies, defining the expectations from the research, case study selection, choosing of data collection method, data collection and analysis and finally deriving the results.

The first step was the preparation phase for the case studies, which included the creation of case study protocol. Using a template for case study protocol based on the guidelines by Yin (2013) forced us to specify in detail the process of answering the research question (Brereton et al., 2008). Having the protocol from the very beginning also helped make the research approach consistent and better structured. Appendix A presents the full case study protocol based on the template suggested by Brereton et al. (2008). The case study protocol addresses case study research Background, Design, Case Selection, Case Study Procedures, Data Collection, Analysis, Validity Plan, Study Limitations, Reporting and Schedule.

Furthermore, to ensure the quality assurance of the paper, we employ the Checklist for Software Engineering Case Study Research (Höst & Runeson, 2007), which includes key questions on Case Study Design, Preparation for Data Collection, Collecting Evidence, Analysis of Collected Data and Reporting. The completed checklist is presented in Appendix C.

As main data collection method we chose semi-structured interviews with employees of different roles at our partner divisions of Siemens. The common characterizes of all the partner individuals was their involvement in UX-related activities in different stages of development. Following the predefined best practice categories, we chose interview partners in both case studies responsible for UX creation, implementation and management.

Data collection also included the study of style guidelines (guidebook of fonts, colors and other key UX components that are common within the product line). Such guidelines serve as the main point of reference for developing consistent UX for the product line, according to our case study partners. The following data was collected:

- 2 interviews related to UX creation
- 2 interviews related to UX implementation
- 2 interviews related to UX management
- Style guidebook
- Other information on each case's product line

The interviews with the individuals responsible for UX helped understand different stages of developing UX at Siemens. The UX creation team's perspective on the UX was a more complete one, as they oversee the UX and usability as a whole. As presented in the related work, UX currently goes beyond usability and functionality aspects of the UX, while focusing also on interactions, user time and contexts etc. This became apparent from the interview with UX creation teams.

The product management team interviews gave the perspective on the product line UX management on development. They oversee the cross-product use of central UX components, as well as have the responsibility to make the decisions on modification or addition of new features and their UX solutions. Furthermore, they prioritize the new functionalities of the upcoming versions of the given software and serves as consistency check for UX within the product line.

The development team interview illustrated the perspective of developers and software architects who are mainly involved in implementation the new requirements and their UX, as well as to some extent the UX testing and evaluation with the customers. This gave insights relevant for the UX implementation best practices.

The data collection was realized in parallel with qualitative data analysis that consisted of coding the interviews using MAXQDA 12 tool. This process included development of codebook for the interviews that would help abstract the data and to consolidate it into the topics of interest. This process also included coding the interviews and using the derived data in synthesizing the results. The codes and their statistics are presented in Appendix D.

Finally, the results are presenting in the form of best practice guidelines in my proposed theory of UX development for software product lines.

2.4.2 Case Context

The pilot case was realized in *syngo.via* department line of Siemens – the product line that is part of Siemens Healthcare division and the group called Syngo. Syngo includes a number of business lines (BL) and syngo.via core platform team. Different business lines specialize in developing various scanner product lines, such as CT or MR scanners and different models thereof, as well as applications for these scanners based on the common basic platform developed by syngo.via. Syngo.via develops the basic applications used and manipulated by different BL-s, as well as the platform used by the BL-s to develop more advanced applications. This product line had a centralized UX team responsible for the core usability and UX components that were available for individual products and ensured the consistent UX for the user.

The second case was realized in *Digital Factory* department of Siemens – the product line around the TIA (Totally Integrated Automation) portal had similar case context in terms of User Experience to that of syngo.via. The product line had a number of products or plug-ins that would connect to the central portal and enable the user to centrally configure and monitor the automated hardware connected to the system. Digital Factory was responsible for the software solution connecting the automation hardware that is also developed by Siemens. The main UX approach was in having a centralized UX team responsible for core building blocks such as tables, trees or text boxes with a defined UI. These components were then applied by each plug-in project team in their respective products or editors. Moreover, the windows of each plug-in and their interactions are also defined centrally, while the semantics of each editor has an individually developed UX by each product team.

The common aspects in both case contexts were the separation of the central UX team and UX experts in each product team, as well as a number of best practices that resulted from this, including the need for central management for some UX components and UX testing, as well as the centrally planned and aligned development and implementation of UX components. These aspects are detailed in best practice patterns in the next section of this paper.

2.5 Research Results

My theory results are presented in the form of best practice patterns in the following three categories:

- UX development or creation
- UX implementation
- UX management

Each pattern is based on the analyzed qualitative data and presents a problem, its context and a solution based on the successful experiences observed throughout the case studies. Most of the best practices include quotes from the interview with our case study partners in order to illustrate the arguments for the given best practice and to ensure their validity.

2.5.1 UX creation best practices

1. Define the UX requirements based on the needs of the customers.

Problem: How to come up with UX requirements? Should they come from within the product line or from the customer?

Context: The UX team internally is responsible for the creation of the UX components and features. In order to do so the product managers and UX team members consults the customers to identify their needs. Afterwards these needs are prioritized and some are chosen to become part of the given software release. New UX components can also come from within the company, for example, as a result of finding UX inconsistencies or if new UX rules are being enforced. Product managers could also use the evolving industry standards to improve the UX.

Solution: When given the choice between the self-initiated UX components and those based on customer needs, the case study partners strongly suggest following the needs of the customers. According to a system architect responsible for UX: *“Generally, the requirements should be formulated in a way to present the user goal.”* Even when the product managers come up with new UX ideas and features, they have the customer need in mind. This approach ensures that most of the customer expectations are fulfilled. Using this approach, our partner at Siemens claimed: *“Normally 80% of the expectations is fulfilled, which is a high degree of expectation fulfillment.”* He adds: *“You normally don’t go with something nobody was thinking about.”*

The main benefit of this best practice is that it enables the evaluation of the given UX component. Based on the need to the customer or its priority, and on the efforts and risk of its development, the usability experts are able to realize value-effort mapping and thus chose the UX priorities for each release. As one usability expert puts it: *“We make a value-effort mapping. We see the value of it (UX requirement). This comes from the product management and value to the customer.”* The implementation team then goes on to evaluate the effort and risk associated with the requirements and based on these factors certain UX requirement get approved.

2. In the initial stage of product line creation, develop a handbook of guidelines and mechanisms of reinforcing these guidelines.

Problem: How to ensure and enforce the common UX and UX consistency in software product lines?

Context: Once the product line is created, there is a need of UX consistency, because the users of the products expect to see similar UX within the product line. However, this can be hard to achieve if the product line is created based on already existing separate products as usually is the case. Such situations create the need for a common guidance when developing the new UX components and making the existing components consistent within the product line.

Solution: The best practice to solving this problem is the creation of a handbook of guidelines or a style guide for common UX of the product line in the early phases of the product line creation. This would improve the learning curve for the users of several applications of the product line due to the familiar UX. Such style guidelines should include atomic and small statements or templates such as definition of fonts and color schemes, in order to overcome the conflicts based on the personal taste.

“Simply having the style guide is not enough”, highlights a usability manager at Siemens, *“so we developed a process where every application has to present in the early concept stages what they are planning to do. Then we check it against the style guide and give recommendations.”* Thus, there is strong need for control mechanism that will ensure the compliance with the guidelines. On one hand, this could be technical checking system that would check the concepts in the early phase of development against the requirements of the

style guidelines and not allow the further development in case of non-compliance. On the other hand, this checking mechanism can consist of strategic approach of certain questions, such as *“If non-compliance to the style guidelines cannot be reasoned as a significant benefit for the potential customers, that is considered personal taste and the inconsistency should not be allowed”*.

It’s important to ensure that this style guide is updated regularly (normally after each release) and corresponds to the current UX needs of the product line. To realize this one of the central UX team members suggests: *“Central team is the owner of the style guide. If we agree with the responsible usability product manager, we edit the style guide.”* However, to avoid too much of centralized control over the UX, it is suggested by our case study partners to include a “Why” section with each style guide component/guideline, that is the reasoning why the given guidelines was included in the style guide. This ensures the transparency and makes the regular updates more objective.

Finally, as a tool for creating the style guide, our partners suggest using either simple word editor or, if the product line is large, use of wiki-like documentation.

3. Develop templates for UX concepts, improve them over time and use them.

Problem: How to create and formulate new UX concepts?

Context: UX creation is considered a creative process, so often the UX creation teams don’t have any templates for suggesting new UX components. Each UX engineer uses the tools he prefers to create UX concepts, for example PowerPoint presentations. However, often there is a need to compare various UX concepts, which can be hard when presentation formats and levels of detail are so different.

Solution: Even though templates are often considered as creativity killers, according to our case studies, if well designed, they can improve the creative process, by stimulating it and putting the necessary limitation and technical constraints in place. The best practice is the development of templates for UX concepts that would include the technical details of the concepts, its mock-ups and description. This templates need to be evaluated and improved continuously to ensure that they are a stimulating tool for the concept development and not another documentation step that is perceived unnecessary and time consuming. The actual usage of such templates would ensure that they evolve and would serve to having better UX development. Having a product line, template will ensure common approach to conception of new features and common UX, because the commonality in development profits the commonality in UX. Moreover, templates save time and efforts of redesigning the basic structure every time, which in case of a product line can be a significant benefit.

This practice is backed by the actual usage in one of our cases. The head of UX team explains the practice: *“So we have a template for concept definitions. Basically, all UX changes are done with use of these concepts. Not only do we define concepts, but there are also some technical aspects to be clarified and there is basically a template that explains what the contents are on the information that needs to be gathered.”*

However, the use of the templates for UX concepts should not eliminate the use of more sophisticated prototypes in the further phases of development. Beyond the UX concept, there is a need for prototypes, static or dynamic. For these instances, our case study partners suggest a freer approach in terms of the toolset used to formulate the UX. In these stages the use of templates is not recommended.

2.5.2 UX implementation best practices

4. Develop a common platform for developing products of a product line.

Problem: How to organize the UX development of various product in a product line?

Context: There are many approaches to software and in particular to UX development in products. For individual product, this problem is often not essential, as the implementation team can use any development tools or languages to achieve the UX goals. However, in case of a product line with many products it can be harmful to have a number of different UX implementation practices, because this can result in inconsistencies and incompatibilities between various products.

Solution: The solution to this problem is in having a common development platform for all the products of a product line. Having a common platform or a tool for developing products of one product line means having the same framework and the same toolset of buttons and other components that would ensure the UX commonality for all the products. Moreover, this means a common implementation and debugging system available across individual products.

According to our industry partners, such a platform is to be set up initially, when the product line is created. It is then utilized for developing the further software products within a common framework. At the same time, a common platform including tools, such as easily passing data from one application another, are a demanded feature by customers and having a common development platform can ensure that an easy data passage can be implemented in each software application.

Once the common platform is established, developers can work on building modules, as suggested by a system architect at Siemens, who is working on fundamental modules that serve the whole platform. Such modular development pattern can be used by any software product line in case of a well-established development platform.

The centralized platform ensures that the core UX components are similarly implemented throughout the whole product line. One tool to achieve this could be the use of so called contracts that each product has to fulfill, when implementing a core UX component. A product manager at Siemens explains: *“Also if you have central functionalities, you have to fulfill contracts, so that your plug-in can contribute to the central functionality. For example, if you open and close the project, or go online, for these functionalities you have to fulfill the contracts so that your plug-in works. If user says “Store” then all the data must be stored. To fulfill this contract, you have to do this and this.”*

5. Create prototypes and test the UX components with customers before integrating them into the product line.

Problem: How to test UX components?

Context: The UX concepts are initially derived from customer needs and formulated by the product managers. Later on UX concepts are presented using templates to give the general idea of the UX and in this form passed to the implementation/development team. The implementation team, however, often has a problem meeting the exact needs of the customers, because the UX requirements are abstract and unspecific. As a result, there is a need of testing various implementation approaches.

Solution: The solution to this problem is to build prototypes for relatively complex and non-trivial UX components and test them with the final customer before integrating them into the product line system. Talking about such UX components, our partner usability manager explains: *“We make a software prototype as well and do it in a standalone application before we bring it into the complex environment. If it works with small software prototype, we use this to evaluate the idea - maybe go to the customer and show it to them, ask “Would it help you in your use case?”. If it's ok, we bring it as a feature. The standard development process starts with that feature integrated in the client site or in the common*

(product line), depending on where the feature should be.” We can infer that for the complex UX components, one could use dynamic prototypes or even standalone apps in order to get accurate feedback from the customer.

However, at the same time the use of such prototyping should not be abused, because presenting a prototype in the early phase of development can force the reviewing customer to get accustomed to the solution presented to him. This would create a bias in the customer feedback and thus result in not the most optimal UX.

6. In UX implementation, use agile development and emphasize the team work & communication.

Problem: What development methods to use in UX implementation?

Context: Among various software development methods, the UX implementation team has to choose the ones that would work best for their needs. These needs include quick adaptability, frequent testing and change in requirements over time based on the customer feedback. In such conditions, the agile development and good communication become essential.

Solution: The solution is to extensively use agile development in order to ensure the responsiveness to the changing requirements and customer needs. A partner system architect at Siemens highlights: *“The trend is to use more agile, obviously, that’s like everywhere.”* He goes on to continue: *“At the end of the day what matters is that you have a good team and good communication.”*

Ensuring good communication or even continuous presence of UX expert in the Scrum team would ensure that all the products of the product line are consistent and develop in the same direction in terms of UX. Our case study partners suggest assigning a UX expert to 1 or 2 Scrum teams.

Furthermore, they emphasize that the consistent communication is key for consistent development and implementation. At Siemens not only are the usability experts involved in everyday work of the Scrum/implementation teams, but they also come together regularly to exchange the development updates from all the teams. Our partner goes on to explain these meetings: *“We all sit in one room and we have good communication hearing and exchanging concepts and ideas.”* Such a practice can enable all the teams to be *“on the same page”*, when developing UX components of whole applications.

2.5.3 UX management best practices

7. Have a dedicated UX department/ team that manages and oversees the overall UX processes.

Problem: Should the product line have a separate UX department/team?

Context: Traditionally the software product lines did not have dedicated UX teams, as illustrated in the related literature, as well as in the interviews of our case study partners. However, over time with the growing popularity and importance of UX in software, the product lines have now the tendency to have a separate UX team.

Solution: The solution many of our partners at Siemens advocate for is to definitely have a dedicated department for usability or UX in the product line. The role of management is key here, because it’s the management that has to recognize the need for having a UX team. This statement is best illustrated by our case study partner and head of a UX team at Siemens: *“We [usability team] got in a session as an official part of the organization and the management is behind this principle to say the usability and UX are as important as the functionality. This is really the biggest improvement you can do in your organization. If only have the impression that the usability guys are just somewhere in the organization*

fighting in the background without any assistance and help from the management, it's going to be, whatever method you use, very hard."

It is recommended to split the UX responsibilities from those of a product manager, who is more focused on functional requirements. At the same time, the UX team has to be in stark contact with the product management, the implementation team and the customers.

8. UX team leader has to have a final say in UX-related decisions.

Problem: Who should have the final say in UX-related decisions?

Context: As UX is often subjective, there is a need for one person making the final decisions related to UX. Even though the UX or usability team members all come together and discuss their ideas, there can be conflicts between them or differences in their UX approaches to a given problem. Such situations need a quick and efficient resolution mechanism.

Solution: The solution suggested by our case study partners is to give the responsibility of making the final decision regarding UX to the team leader of the usability team. As one of developers puts it: *"Yes, there is one responsible person that in the end can say that from the usability point of view, it must look like this". And then there is a decision. Especially in the UX, in the end there must be a final say. It's not black and white. Sometimes you can see it this way, I can see it in another way and both are ok."*

This person is regarded as a bracket that takes into account the concurrent ideas and concepts and synthesizes a final decision. For example, it's the responsibility of the UX team leader to decide which concepts have to become part of centralized UX and which will remain in individual products. Moreover, the UX team leader can manage the UX experts in individual products in cases when he sees that several products are working on a similar UX components, or if the UX solution of one product could be reused and applied to the other product, too. The coordination and synchronization of these activities is the responsibility of the UX team and its manager.

9. Manage time in a way that 20% of each UX expert time is used to explore new concepts and tools.

Problem: How much time should the UX experts have for learning new concepts?

Context: UX is a relatively new domain in software development and it's becoming more and more widespread quickly. This means that a lot of new concepts and tools are being constantly developed, thus driving the demand for innovative UX by the clients. This means that the UX experts in product lines cannot spend all of their time improving the existing UX components. They need to spend some time learning new UX concepts and tools.

Solution: The solution suggested the head of the UX team whom we interviewed is to assign the UX experts to spend 20% of their time on learning new UX concepts and acquiring new skills. This is both motivating for the employees and useful for the company that is up-to-date with the current UX solutions. Our partner at Siemens says: *"Everybody should have 20% time to see other things, to experience and try other things. So everybody goes that way and then one comes and says I saw this solution, it's not bad, let's see."* This is an encourage practice that gives valuable benefits.

2.6 Limitations and Conclusions

The main limitation of this research is that it's based only on two cases. This limitation could bring to somewhat subjective or biased results based on these two product lines. However, the

future research can apply and validate the best practices presented in the paper, so these limitations can be measured.

These nine best practices derived from the case studies at two independent Siemens product lines illustrate the common industry practices in UX development, implementation and management. Even though, somewhat subjective and limited, these resulting guidelines are derived from the actual industry best practices. Therefore, they can be used by new software product lines in their UX-related activities as a general guideline.

2.7 Acknowledgements

Finishing this paper, I would like to acknowledge my academic supervisor – Dr. Prof. Dirk Riehle who was very supportive during the whole process of this research starting from the providing contacts with the potential partners and finished with thorough feedback of my continuous work.

I would like to acknowledge the case study partners from Siemens, who were willing to provide their valuable time and insights on the topics of user experience in software product lines. They were very cooperative and reliable.

I would also like to acknowledge the reviews of my work for their fair recommendations and valuable suggestions.

Appendix A Case Study Protocol

1. Background

- a) identify previous research on the topic – literature on non-functional aspects of UX in software product lines was reviewed and helped formulate the research and interview questions.
- b) define the main research question being addressed by this study – “What are the best practices employed by software product lines while dealing with User Experience?”

2. Design

- a) identify whether single-case or multiple-case and embedded or holistic designs will be used, and show the logical links between these and the research questions – Multiple-case and embedded design is used, because the best practices are based on the integration of data from multiple cases and each best practice has embedded components from both cases.
- b) describe the object of study – UX in two Siemens software product lines.
- c) identify any propositions or sub-questions derived from each research question and the measures to be used to investigate the propositions – three categories of best practices are considered including UX creation, implementation and management. The main measure to ensure their investigation is qualitative data analysis, including separate codes for each category.

3. Case Selection

- a) Criteria for case selection – The main criteria for two Siemens cases were the proximity of the company, their interest in UX research and cooperation with the university, as well as the existence of established, yet unstudied UX practices within their software product lines.

4. Case Study Procedures and Roles

- a) Procedures governing field procedures – Initially the interviews were scheduled with three members in the pilot product line. The prepared interview questions were asked to three case study partners during visits to the company or online (via online communication tools). The same procedure was then applied for the second case.

5. Data Collection

- a) identify the data to be collected – The main source of data collected from the case studies were semi-structure interviews (for questions see Appendix B) with partners of different UX-related roles in the given product line. The goal was to interview one person engaged in UX creation, another person in UX implementation and one in UX management in order to match the three categories of predefined best practices.
- b) define a data collection plan – The interviews from the pilot case study were recorded and transcribed. The related documents about the UX in the pilot product line were also collected. While analyzing the pilot case’s data, the data was similarly collected from the second case.
- c) define how the data will be stored – The data was stored digitally as audio and text files.

6. Analysis

- a) identify the criteria for interpreting case study findings – As part of qualitative data analysis, a coding system was developed including separate codes for three best practice categories, UX creation, implementation and management. These codes were mainly used to integrate and interpret the case study findings.
- b) the analysis should take place as the case study task progresses – the analysis of the pilot case study took place as the data collection of the second case study was collected.

7. Plan Validity

a) general: check plan against Höst and Runeson's (2007) checklist items for the design and the data collection plan – The checklist is presented in Appendix C. It was utilized for quality assurance and validity of the qualitative data analysis.

b) construct validity - show that the correct operational measures are planned for the concepts being studied. Tactics for ensuring this include using multiple sources of evidence, establishing chains of evidence, expert reviews of draft protocols and reports – The validity was constructed based on the multitude of data sources, mainly including three interview partners in each product line and product line related documents on UX, such as style guidelines.

c) internal validity - show a causal relationship between outcomes and intervention/treatment (for explanatory or causal studies only). – The well-defined codes for qualitative data analysis ensured internal validity by showing the relationships between different data sources and the respective best practices.

d) external validity – identify the domain to which study finding can be generalized. Tactics include using theory for single-case studies and using multiple-case studies to investigate outcomes in different contexts. – The theory using multiple case studies ensured the external validity, however limited by the number of case studies, by providing independent product lines and their UX practices. The synthesis of two case studies helped yield best practice theory applicable in the general domain of UX in software product lines.

8. Study Limitations

Specify residual validity issues including potential conflicts of interest (i.e. that are inherent in the problem, rather than arising from the plan). – Interviewing only the company representatives, one limitation was that the point of view of the final UX users was not taken into account directly. However, as the study was focused on the UX practices within product lines, this was not a significant limitation.

9. Reporting

Identify target audience, relationship to larger studies (Yin, 2013) – The target audience of our paper is the academic community interested in UX research, particularly UX in software product lines, as well as the industry actors in the field of UX in software product lines. This study can be considered as part of the larger UX research domain that goes beyond software product lines.

10. Schedule

Give time estimates for all of the major steps: Planning, Data Collection, Data Analysis, Reporting. Note Data Collection and Data Analysis are not expected to be sequential stages – The research was realized within 6 months, of which 1 month was used on planning, 1 month on data collection, 2 months on data analysis and 2 months on reporting. There were overlaps between the major steps.

11. Appendices

a) Validation: report results of checking plan against Höst and Runeson's (2007) checklist items – See Appendix C.

b) Divergences: update while conducting the study by noting any divergences from the above steps. – There were no major divergences from the steps above.

Appendix B Preliminary interview questions

Main research question: What are the best practices of software product line user experience?

Interview questions

// Syngo.via/Digital Factory and the role of the interviewee

1. Could you briefly explain the syngo.via/Digital Factory division's organizational structure?
2. What is your role in syngo.via/Digital Factory team and what are your main responsibilities?
3. Who are the main people involved in product line UX development and management at syngo.via/Digital Factory? What are their main responsibilities?

// Syngo.via/Digital Factory product line

4. How do you define a product line at syngo.via/Digital Factory?
5. Could you explain the product line structure of syngo.via/Digital Factory? What specific product are considered to be part of the product line?
6. What are the defining boundaries/scope of a product line?
7. How are different product lines connected, especially in terms of UX?
8. What is the competition for the syngo.via/Digital Factory product line? Do you use benchmarks for the UX of your product line?
9. What is your standing in comparison with the competition? How is your UX different? What are the forces and weaknesses?
10. Who are the main clients of syngo.via/Digital Factory? How different products of syngo.via/Digital Factory product lines address different client needs?

// User experience

11. How do you define/explain the user experience at syngo.via/Digital Factory? Is it more than user interface usability?
12. Describe the process of inventing the user experience.
13. Could you describe the user experience at syngo.via/Digital Factory product line? What are the main characteristics and components?
14. What are the common UX components of syngo.via/Digital Factory product line?
15. What are the individual/distinguishing UX components of syngo.via/Digital Factory products?
16. How did the UX develop over time? How do functionalities change?
17. Who are the main stockholders of the syngo.via/Digital Factory UX?
18. Who suggests new UX components and functionalities, as well as their requirements?
19. How are the suggested functionalities evaluated and prioritized?
20. As a product manager, do you use specific prioritization techniques or tools?
21. How are new functionalities developed/implemented?
22. Is there a UX review process or post-implementation phase? Describe it.

// Best practices of UX and process

23. Do you have documented UX best practices or UX guidelines for product lines?
24. How would you evaluate the UX conception process at syngo.via/Digital Factory? What are some best practices you could identify, documented or not?
25. What are some of the flaws of the UX conception process at syngo.via/Digital Factory? How could you improve them?
26. Are there some best practices you used or documented as a product manager?
27. Are there any practices you reused in your work or could identify as efficient for UX development for product lines?
28. Are there any practices/activities that make UX development better/more efficient?
29. What criteria would you identify as defining for best practices?
30. How could best practice handbook be useful for syngo.via/Digital Factory?
31. What would you like to see in the best practice handbook?

// Optional: UX economic value

32. How do you evaluate the economic value of user experience components/ functionalities?
33. Is there a model for assessing the UX components?
34. Do users/clients give you feedback about their perceived value of each UX component?
35. Do you need an economic value evaluation model for the UX components in the product line?
36. Describe the business model of syngo.via/Digital Factory? How is the UX (development) involved? Only as a cost, or something else?

// Follow-up questions

37. Do you have any documentation about the UX of syngo.via/Digital Factory product line, its development process or used best practices?
38. Could we interview some developers of your team? Who would you recommend for better understanding of the UX conception?

Appendix C Checklist for Software Engineering Case Study Research (Höst & Runeson, 2007)

Researcher's Checklist

Case Study Design

1. What is the object of study? – UX practices in two independent product lines at Siemens.
2. Is a clear purpose/objective/research question /hypothesis/proposition defined upfront? – This exploratory case study research attempts to answer the following research question: "What are the best practices employed by software product lines dealing with UX?"
3. Is the theoretical basis - relation to existing literature and other cases - defined? – Yes, the section on Related Work defined the theoretical bases of the study, as well as compares and contrasts the study findings and the existing literature.
4. Are the authors' intentions with the research made clear? – The research intentions are clearly defined in the Research Question section of the paper.
5. Is the case adequately defined (size, domain, process...)? – The case contexts are described in detail in Research Approach section.
6. Is a cause-effect relation under study? If yes, is the cause distinguished from other factors? – In the Research Results section, each pattern represents a cause-effect relation based on the relevant data and factors.
7. Will data be collected from multiple sources? Using multiple methods? – Multiple sources are used, including three interviews in each product lines and related documentation, such as style guides etc. Semi-structured interview and document review are the methods used in data collection, while qualitative data analysis is the method of data analysis.
8. Is there a rationale behind the selection of roles, artefacts, viewpoints, etc.? – Yes, three case study partners are chosen to reflect the best practice categories predefined in the study, including roles in UX creation/design, implementation and management.
9. Is the integrity of individuals/organizations taken into account? – Yes, each product line is studied as an integral organization with its own practices.

Preparation for Data Collection

10. Is a protocol for data collection and analysis derived (what, why, how)? – The case study protocol is defined in Appendix A. It addresses all the major steps of the case study research, in order to ensure the quality assurance and consistency within the research process.
11. Are the planned methods and measurements sufficient to fulfil the objective of the study? – Yes, qualitative data analysis methods are sufficient to fulfil the objective of finding the UX best practices derived from the study of the collected data.
12. Is the study design approved by a review board, and has informed consent obtained from individuals and organizations? – The study design is approved by the responsible university department and the informed consent is obtained from both the individuals and organizations of case studies.

Collecting Evidence

13. Are data collected according to the protocol? – Yes.
14. Are data recorded to enable further analysis? – Yes.

15. Are sensitive results identified (for individuals, organization or project)? – Yes, sensitive results are identified.

16. Are the data collection procedures well traceable? – Yes, using qualitative data analysis methods.

17. Do the collected data provide ability to address the research question? – Yes.

Analysis of Collected Data

18. Is the analysis methodology defined, including roles and review procedures? – Yes, the qualitative data analysis methodology is used, in particular the tool MAXQDA 12.

19. Is a chain of evidence shown with traceable inferences from data to research questions and existing theory? – Yes, as quotes and supporting data in the Research Results section.

20. Are alternative perspectives and explanations used in the analysis? – Yes, each phenomenon/ best practice is coded and includes references to the alternative perspectives and arguments.

21. Are there clear conclusions from the analysis, including recommendations for practice/further research? – Yes, best practices are the clear conclusions of the study. They include recommendation for practice for UX in software product lines.

22. Are threats to validity addressed in a systematic way? – The threats to validity are minimized using the rigorous qualitative data analysis methods, case study protocol and case study checklist.

Reporting

23. Are the case and its context adequately reported? – Yes.

24. Are the research questions and corresponding answers reported? – Yes.

25. Are the data collection procedures presented, with relevant motivation? – Yes.

26. Are sufficient raw data presented? – Yes.

27. Are the analysis procedures clearly reported. – Yes.

28. Does the report contain conclusions, implications for practice and future research? – Yes.

38. Is the report suitable for its audience, easy to read and well structured? – Yes.

Appendix D Qualitative Data Analysis Coding Statistics

Code System	Memo	#
Code System		154
context		0
company	Describes the context of company - including the basic information about the company.	5
product line	Describes the product line, its products and their interactions.	15
management and organization	Describes the context the management of a product line and its organization.	16
best practice		0
creation/design best practices	Highlights best practices of design and creation of UX in product lines	45
implementation best practices	Highlights best practices of implementation of UX in product lines	40
management best practices	Highlights best practices of managing product lines	33

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