User Experience in Machinery Automation: From Concepts and Context to Design Implications

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Abstract. Machinery automation (MA), e.g. different agriculture machinery, has traditionally been developed by experts in automation and in machinery engineering. As the role of interactive software is increasing, the principles and methods of human centered design (HCD) are being applied. This results in better usability of the systems particularly through efficiency of work processes and user interfaces (UIs). The user experience (UX) approach extends the HCD approach with broader motivational factors of using the systems. This paper describes the elements of UX in the MA from the interaction design perspective. After introducing the UX field, we describe the context to give an overview of the major factors affecting UX. Then we present what we consider to be the key elements of UX in MA and what implications they bring to the design of such systems. Finally we discuss the benefits and challenges of applying UX in this particular field.

Keywords: Human centered design, interaction design, MA, user centered design, user experience.

1 Introduction

Traditional usability, as defined by ISO [1] gives only little attention to what the user thinks about the system. The major concern here is how the term satisfaction is understood. The current definition does not encourage the designers to consider broadly how this satisfaction is achieved, but rather leave it in to too little attention, presuming that once the usability engineering is done right the user will be satisfied. Hassenzahl et al call this kind of tendency as usability reductionism [2]. The concept of User eXperience (UX) has emerged to bring user's motivation and thoughts more into designers' attention. UX has been researched from many perspectives, see e.g. [2, 3, 4, 5, 6, 7], but the practical applications of the theories can still be viewed as immature.

The practical applications of UX design and evaluation have been focusing on consumer products [8]. In machinery automation (MA), applications of UX principles have not been reported. By MA, we refer to the control and manipulation systems of different mobile machines, e.g. various agriculture and forestry and construction machinery.

We present the basic concepts of UX in section 2. UX is related not only to user interface (UI) design of the products but also on designing the right functionalities and the interaction mechanisms and styles to support users' tasks and values.

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In the 3rd section, we describe different contexts in MA and present typical product features such as the interaction styles and content in these contexts. In the 3rd and 4th sections, our findings from earlier case studies are reflected against the UX framework by Hassenzahl [3]. Our case studies and current industry practices are briefly described at the end of this introduction section.

In section 4 we present the design implications that UX perspective brings in to MA. We give examples of how the operator's motivation and development is supported in current systems and how the UX perspective can be used to create more appealing systems. These include e.g. supporting user in following and developing his/her personal growth and supporting professional identity as well as social needs.

1.1 The Case Studies Behind the Context Knowledge

During the recent five years, we have carried out more than ten case studies in the MA field. These studies vary from simple heuristic evaluations to designing a new product family. We have focused on several different user groups, e.g. maintenance, assembly and different operators. Majority of our work has involved forestry or mining industry, but we also have conducted some case studies in process automation and logistics and transportation. All of the case studies were highly product development orientated, while most of the studies contained academic research component as well. Our main focus has been institutionalizing human centered design, see e.g. [9, 10] and developing usability methods in this particular field. An integral part of the case studies has been carrying out dozens of field studies applying contextual inquiry [11]. We have extensively applied also other parts of the contextual design method [12] in our case studies.

While UX is a relatively new concept, we originally have not had it in the design or research focus in these case studies. However, with this paper we want to reflect our previous findings against UX theories and illustrate how UX perspective supports the designers in developing more engaging systems in this complex application area.

1.2 Current Design Practices in the MA Industry

In our studies during 2005-2009 we have followed and evaluated closely the design practices of five separate organizations in the MA industry. The design traditions stem strongly from sources other than software, HCD or UX design. However, most of the organizations we have covered have some usability professionals within, and their number is increasing. The design is customer oriented and the needs of internal stakeholders, e.g. maintenance and assembly are well covered. The end user is rarely represented in the design process, but the designers have relatively good understanding about the end users and their work. The concept of usability is well understood widely in the organizations, although HCD principles are not completely followed in the design process. The design processes are currently being altered to better suit to iterative design and to support software development, including more systematic requirements engineering and introduction of sets of standardized usability methods to be used during the process. For further information, see [9]. So far, the concept of UX is very new for the people in the industry, and our main concern remains in institutionalizing

HCD in the organizations. However, the usability professionals in the industry have accepted the concept of UX with enthusiasm and expect concrete design ideas from it.

2 User Experience (UX) Concepts and Frameworks

User eXperience (UX) refers to all aspects of the end-user's interaction with the company, its services, and its products [13]. From a more theoretical perspective, Hassenzahl & Tractinsky [7] have defined UX as "A consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organizational / social setting, meaningfulness of the activity, voluntariness of use, etc.)". Furthermore, UX includes a mixture of pragmatic and hedonic experiences [7], arising from product characteristics that are functional or non-instrumental in nature. Functional characteristics support practical goal-orientation and hedonic aspects of use support users' goals such as social relatedness, development of personal skills and knowledge, and self expression i.e. users' need for joy, enjoyment, identity, and inspiration.

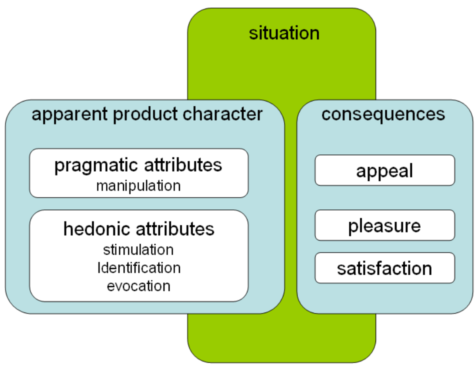

Fig. 1. The core of Hassenzahl's user experience framework [3]

Hassenzahl states that the key elements of the UX are the product features, the product character and the consequences [3], see Fig.1. The product features include content, presentation, and functionality and interaction style. The product character is a high level description - a holistic abstraction - of perceived features. This product character includes the pragmatic and hedonic attributes. The consequences refer to the judgment about the products appeal, and the emotional and behavioral consequences, e.g. pleasure and increased time spent with the product.

This paper refers to Hassenzahl's UX framework since we found it best supporting the considerations of applying UX on MA. It gives a rich picture of UX, particularly, when accompanied by the explanations about the volatility of user's expectations and about the user's goal/action mode (see [3]). In this paper, we focus on the hedonic product attributes, since the pragmatic ones are well covered by more established usability paradigms. Findings by Hassenzahl [4, 14] showed that the hedonic quality substantially contributed to the overall appeal of software prototypes for process automation control tasks.

3 The Components of the UX in MA

In Hassenzahl's framework, the UX is consisted from the product features, the product character, the consequences and the situation (context). In this section we give examples of these elements in the MA. Since UX is highly dependant on the user, we start by describing briefly the users (operators) and their values in this domain.

3.1 Operators and Their Values

The operators are in many cases highly goal oriented, particularly if their salary is based on their performance and productivity. They are aiming to achieve certain end product quality with maximum productivity. They are also concerned in keeping the systems functioning all the time and lowering the operating costs. Due to the physical risks involved, the operators are or at least they should be interested in work safety. There are also observations of less motivated operators who show no remarkable interest in using the system more than the absolute minimum. Part of the operators is very concerned about the expensive machinery and they fear that they may damage them. Sometimes working in isolated locations may add this stress, since the operators know that when facing troubles, there is no instant assistance available. Depending on the training and other experiences, the operators may or may not be concerned about the environmental issues related to their job.

The training may vary from scratch to several years of formally regulated training, even for the same particular product, when used in culturally different areas. Also the computer literacy, as well as the traditional literacy varies from illiterate to fluent.

3.2 The Context and the Situations in MA

The systems are typically equipped with a combustion motor and they are often mobile. In addition, the systems often contain hydraulic manipulators. Major part of MA is used in contexts that are extreme in many scales. Although many consumer products, like mobile phones, PDAs and sports computers are used outdoors or even underwater, there typically are not as much hazardous elements present as in the environments that are common for MA. Also, typically the context in which a consumer product is operated can be selected more freely.

Good examples of harsh and dangerous conditions can be found from forestry, mining [12] and construction. E.g. harvesters and stone crushers are operated within a temperature ranging from -50 to +60 degrees in centigrade. This is not only limiting viable technical solutions, but it also affects the human behavior and indeed is a central part of UX. Other disturbing context factor is the danger caused by the moving machinery and the processed materials, like stones or timber. In a quarry, there is a lot of dust from the stones making it difficult to see and breathe properly. The dust easily covers different surfaces and also taints the hands of the user. When using a stone crusher UI, the operator typically has to start the sequence by wiping the dust off the display. The dust covers also the physical buttons and their labels, as depicted in

(Fig. 2). The operator of a stone crusher or a harvester occasionally needs to service the equipment which also smears his/her hands, and there rarely is a place to wash them nearby. The materials and devices touched by the operator become therefore smudged, so e.g. some parts of the paper manuals may become unreadable.

Fig. 2. Detail of a dusty user interface of a stone crusher

The noise, particularly in a quarry can reach 125 dB, making it difficult to communicate with others and causing fatigue and stress to the users. In some cases the machinery vibrates and experiences high acceleration shocks, which has physically tiring effects and makes it harder to see small details from the displays or buttons attached to the machinery. Also the accuracy to use buttons and touch screens suffers due to vibration.

3.3 Tasks

Majority of our case studies have been carried out in the forestry and the stone crushing industries, which represent two extremes of MA usage. While a harvester machine operator is using the automation system UI most of the time, a mobile stone crusher operator is mainly occupied by tasks that do not involve directly monitoring or operating the system. In general, operator's task include

- Controlling and monitoring the process
- Solving problems (breakdowns, quality and efficiency problems)
- Collecting and analyzing statistics
- Using information from other systems, e.g. details of the production, customer orders, map information etc.

The operator often needs to use several different applications for different purposes, which, when used in combinations, raises the cognitive requirements of these tasks.

3.4 Product Features and Interaction Style

The systems are often a mixture of desktop applications and embedded systems. Typical UI consists of both display and numerous hardware buttons and controls for different tasks (see (Figure 3)). The content used in the system is most of the time a limited set of measurement data from the system or a selected set of parameters which the operator is using to modify the system behavior.

Fig. 3. The view from the harvester machine cabin

The navigation is based on hierarchies which are typically defined by the system structure or functionality. In many cases, there are standards and safety regulations constraining the UI design.

When considering what kind of interaction there occurs, we find a recent classification by Dubberly et al [15] useful. Interaction between the system and the user is characterized by classifying the systems in question into three different categories, i.e. linear systems, self-regulating systems, and learning systems. In our contexts, the operator may be interacting with all three types of dynamic systems. For example, when the operator controls the simplest actions of the harvester head, he is interacting with a linear system. While controlling the movements of the hydraulic actuators, the operator is interacting with a self-regulating system, i.e. a system that is using both the data from its sensors and the input from the operator to regulate its actions. When making decisions about how to cut a tree trunk, the operator is interacting with a learning system, that offers optimized suggestions based on what type of logs are needed and what the system has learned from the properties of the current location's trunks. Based on different combinations of interactions between systems, there are at least seven different interaction types [15]:

- Reacting to another system
- Regulating a simple process
- Learning how actions affect the environment
- Balancing competing systems
- Managing automatic systems
- Entertaining (maintaining the engagement of a learning system)
- Conversing

While entertaining and conversing are perhaps not in the mainstream of the current MA systems, the future systems have inevitably more of these features, since the level and sophistication of automation in these systems is increasing. With level of automation

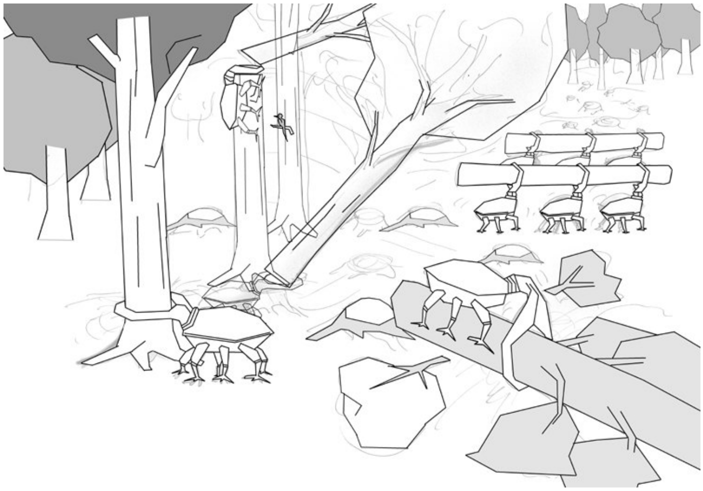

Fig. 4. Vision of future harvester work [17] (published by permission from the author)

[16] we refer to in how extensively the system informs the operator, asks permission to actions and/or acts autonomously.

The long term trend is letting the operator focus on high level tasks and having a system to take care of simpler control tasks. An extreme example of how the interaction may change is a futuristic concept vision where the future harvester operator is controlling an army of compact forestry robots [17]. The robots autonomously take care of most of the harvesting, see Fig. 4. The operator would probably have “conversations” with the system before making important decisions, and in order to learn to use the system fully, the system has to entertain the user in some extent to motivate him/her to study and learn enough about it.

3.5 The Product Characters

When referring to the product character (see fig. 1), we omit the pragmatic characters covered by traditional usability engineering and concentrate on hedonic attributes.

According to [3], there are two major types of hedonic attributes – the ones concerning the individual’s personal development or growth and the ones concerning social and societal issues. Many current systems do support both sides to some extent, but neither of them has been in the design focus so far.

Typical systems have relatively traditional online help systems explaining the functionality and the purpose of different system parameters. One recent application for harvesters assists the operator in analyzing his own performance and this way supports the operator’s personal development. This can also lead to consequences such as higher motivation to use the system and to find out about other functionalities in it.

Some other features help with communicating with the customers or co-workers working e.g. in another shift. Currently, e.g. in forestry, communication with the customers is supported only through highly technical means, by delivering order and production information with a certain protocol. Social issues in general have been considered only a little in the design of current MA systems.

4 Design Implications Emerging from the UX Perspective

The harvester operators are highly concerned about their responsibility of the machinery. The harvester machines are costly and complicated systems, and the risk of doing something that might harm the equipment is bothering the operators. The operators work often in solitary locations with no one else present to help with possible technical problems. Lowering this stress by supporting them better in problematic situations and indicating the health status of the system in an understandable manner would probably improve the overall UX. Also, offering more efficient ways to communicate about the system status and about operator's personal working style with maintenance personnel or other specialists would improve the situation and help the operator to develop professionally.

The majority of the tasks done with stone crusher and harvester UI are repetitious and routine and the operator knows automatically how to do them. This leads to several implications on UX design. Firstly, the task flow has to be concentrated highly on effectiveness and efficiency, which is an area well covered by traditional usability engineering. Secondly, the novelty of new solutions for these tasks must not be exaggerated. Otherwise the users may be frustrated when they need to relearn their daily routines. Multimodal feedback and input is already in some use and it can be further exploited to offer interactions that are both efficient and offer good UX.

People need an optimal level of excitement and challenge to experience flow [18], and e.g. [3] suggests that novelty and change would assist in this. Some tasks done with the systems are monotonous, which imposes a challenge to motivate and stimulate the user without jeopardizing the efficiency and safety of the tasks.

The operators' attitude and behavior differ due to the nature of their tasks and also due to the differences in the systems. When the operator is not actively involved in the process, there is a risk of the operator loosing interest in the system and therefore being unable to notice early enough when the process is going to an unwanted state.

On the other hand, e.g. for harvester operators, the flow experience is already present in the form of competing with one self's and in the challenges of making optimal, accurate and speedy decisions about the process based on the observations from the environment and the feedback and measurement data from the system. Skilled harvester operators are like race car drivers who are concentrating on their task with maximum intensity. A chance to enhance UX in this kind of situation might be offering the user more accurate and incentive information about their performance, perhaps even developing metrics that would help them to compare their earlier and current performance under different circumstances. Later, social hedonism could be supported by enabling sharing one's results and hints to the user community.

5 Conclusions and Discussion

The UX concept is a recent addition in the usability field in its long term development from merely cognitive considerations to more social and emotional considerations (see e.g. [19, 20, 21]). There are several reasons to assume that the UX paradigm will influence the MA industry. The level of automation is increasing and the nature of work is shifting from monotonous, low level process control towards expert and team work. Also the consumer market will eventually train the operators to demand the work systems to offer better UX. Therefore we expect that the hedonic attributes will have an important role in designing the future MA products.

It will be challenging to take into account such factors as user's need to develop and express oneself and to be socially connected to others, while maintaining safety and effectiveness and compliance to different regulations typical for these contexts. Due to this fact, particularly in MA, there is a strong need for conservative solutions. Designers should avoid compromising usability e.g. in order to design more novel and exciting products. We would also like to discuss the emphasis on hedonistic attributes and avoid them being judged as if they were of "higher" value than the pragmatic ones. There are two risks. One is forgetting that for most products, there is some pragmatic reason for their existence. The other risk is, that hedonism is understood too literally as a pursuit of simple pleasure, while joy of first working hard to achieve something is an integral part of enjoying what you have achieved, reminding of the flow experience [18].

It may be a good idea to seek design ideas from the UX perspective after the fundamental usability work is in a mature state. On the other hand, there are indications that good UX may compensate for shortcomings in usability [4, 14]. UX point of view is more effective than the traditional usability perspective in helping the designers to understand and support the user's hedonic values, like the need to develop and express oneself and to be socially connected to others. Particularly, both researchers and product developers need more experience with different methods for developing, evaluating and measuring UX.

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