Challenges For Designing Tangible Systems

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ABSTRACT

Since the introduction of tangible systems and tangible interaction a lot of work has been done in this area. The focus for most of these works was on a success of tangible interaction and few papers discuss when tangible systems fail. In this paper, we aim to understand what we can learn from the failures of tangible systems. We discuss the challenges raised during the design of tangible systems and present a list of research questions for future exploration.

INTRODUCTION

Tangible interaction has been a widely researched area since the work by Ishii and Ullmer [9]. During this period of time there were both positive and negative experiences with tangible systems. Hornecker and Buur [7], for example, have shown that tangible interaction is engaging and provides a low threshold for accessing interactive systems. Ishii and Ulmer [9] showed that tangible systems are successful in facilitating the smooth transition of attention between foreground and background tasks, what makes them successful for the increase of awareness. Shear and Hornecker [14] provided scenarios and recommendations regarding the future development of tangible interaction. While most of the works focus on the positive aspects of tangible interaction, we decided to make a closer look at the negative experiences and problems with tangible systems and what we can learn from it. Throughout the exploration of related work we were aiming to answer the following questions: (1) What is this about tangibility that makes things work and what not? (2) Till what extend one can use tangible interaction? (3) Where does the tangible interaction fail?

To find the answers to these questions, we analyzed existing tangible systems. As a results, we derived a list of challenges from the experiences with tangible systems, which we describe and discuss in detail in the following section.

CHALLENGES FOR DESIGNING TANGIBLE SYSTEMS

In this section we aim to outline some of the problems and challenges which raise during the process of design and interaction with tangible user interfaces. Based on the previous work and our own experience, we discuss the following aspects of tangible systems: (1) scalability, (2) acceptability, (3) novelty and complexity of interaction, (4) form factor and context of use and (5) maintenance and complexity. In the following we discuss in detail each of the aforementioned dimensions.

Scalability

Designers of new tangible systems are often trying to maximize the scalability of a system they are developing. In some cases this is needed to enable the use of the system by multiple users or to integrate different modalities into an artifact. However, the level of a scalability is still limited in comparison to a smartphone application, and often increases the complexity of a tangible system. Couture et al. [3], for example, studied whether a tool with a generic form factor can be scaled and substitute tools with a dedicated functionality. However, systems that support an extension of contacts [5, 20], different kinds of notifications [1] or modalities [8] still have an extension limit. The questions that are raised: “What happens if the number of communication partners increases to 100?" or “What if I have five types of notifications instead of one? Do I want to have five notification objects on my desk?" Matviienko et al. [11] tried to solve this issue with a tangible modular calendar by letting the users assign and reassign a contact to a dedicated tangible figure. Even though these artifacts have been developed with a possible scalability in mind, they are still restricted in comparison to most software systems. The extension of tangible systems in comparison to smartphone applications is demanding more resources and is harder to realize in the late stages of the development process. One of the research questions to explore in the future work would be: *“How can we design tangible systems with simplified scalability?"*

Acceptability

Acceptability and integration of new tangible systems in people’s environment is another challenging aspect for designers and developers. Systems which are designed in the form of a flower [20], a tree or a house are not immediately accepted, if at all. Even though people are used to tables and desks in their working environments, the artifacts in the form of a table [19] would require some time for a user to get used to it. Moreover, people get often attached to specific artifacts from their environment, since they inherit memories from their past [2]. When designing artifacts that replace existing objects, it is important to involve users into the design process or integrate existing objects into the design.

Users who use portable tangible systems, such as CubeLendar [12] or Forget-Me-Not [20], often face problems of acceptability, since taking an object to a location uncommon for the usual interaction might raise social concerns or is annoying to the users. It is a long process of accepting and adapting to a new tangible artifact in the environment, especially when designed to be used in various contexts of use. For example, an artifact which has been designed for domestic environment might not

fit into a workplace. As a consequence, users tend not to use the systems in different context. It affects users' interaction with a system and can provide misleading information in field experiments.

Another challenging aspect regarding future tangible system is to investigate the change of interaction with the same functionality developed as a mobile application and as a tangible object. Users usually do not face problems using new applications on their smartphone, but need time to get used to new tangible systems. What is missing in tangible objects for increasing their acceptability? This leads us to another research question: *"Which properties of tangible objects can help increasing users' acceptance?"*

Novelty and Complexity of Interaction

Different software applications imply interaction with the same physical object, e.g. smartphone or laptop. The interaction paradigm for software systems is often consistent due to standards and best design practices. Tangible artifact, however, have various form factors. Therefore, a user has to learn an interaction for a specific object and adapt to its affordances. Ullmer et al. [17, 16, 15], however, tried to solve this issue by presenting physical interaction elements which can serve common roles across different tangible systems. Furthermore, physical objects are not mutable, and are not able to change their physical representation as it would be possible with digital systems, e.g., change a button state [13], undo or a history function [10]. This can be a challenging aspect, especially when designing for non-technical users like children or elderlies. To reduce complexity of the interaction and to ease the way users are interacting with an artifact, designers of tangible systems have to carefully select solutions and involve users as early as possible into the design process. This might include brainstorming sessions to get insights into users' needs, low-fi prototyping sessions together with users to get early feedback on form and size of tangible artifacts and continuous user evaluations within a realistic context of use. Another research questions to explore here would be: *"How can we design tangible systems with minimized novelty effects and complexity of interaction?"*

Form Factor and Context of Use

Some of the tangible systems are restricted to the environments where they can be used. The form factor of a tangible artifact is one of the reasons. If one uses an ambient light on the lamp [4] to encourage people to move more at work, she cannot take it home as easily as a smartphone with a fitness application installed on it. The systems such as the information percolator [6] is a stationary system integrated into environment, which can function and show information in the environment, where it was installed. Other examples like the StoryBox [18] can be used to support children and elderlies to easily create and share stories within a domestic context. Due to the interaction concept, the box has certain form factor constraints with regards to its size, and relatively large size might not be accepted by all users within their homes. Therefore, the form factor of tangible systems might restrict the context of use and often raises acceptability concerns by users, especially when used within a domestic context. The designers of tangible artifacts should further not only consider affordances through physical shape, but also take ergonomics into account, which are especially important for longer-term usage of systems. This leads us to another research question: *"How can we design tangible systems with a flexible context of use?"*

Maintenance and Complexity

After all, maintaining tangible systems for research purposes is cumbersome in comparison to software applications. When such applications fail, a researcher can update the software remotely or provide an exchange device with an updated application. When a tangible system fails, one has to either fix the whole system or as in the case with smartphone application provide a new one. However, building a new tangible system as back-up is more time and costs consuming than a pure software application.

A tangible system usually consists of a multiple hardware components. These components have to communicate with each other by exchanging data to ensure that a system works as one module. The more components are integrated in a tangible system, the higher its complexity, the harder its maintenance. Another research question here would be: *"How can we design tangible systems with a simplified maintenance?"*

CONCLUSION

We presented some of the challenges in the application of designing and developing new tangible systems from our own experience and from other related works. The design and evaluation of tangible interfaces with users in a realistic environment can be challenging and requires a lot of attention by researchers and designers. Although, this is an important topic, these challenges rarely get reported or reflected after an artifact has been designed and implemented into the field. This work is far from being conclusive, but rather is meant to create starting points for discussion. We hope that reporting some of the challenges will assist future designers of tangible systems and avoid the identified issues.

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