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Extending the engineering trade-off analysis by integrating user preferences in conjoint analysis

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ABSTRACT

The ongoing technical improvements in architecture design with improved features of mobile or smartphones do not automatically guarantee user acceptance, because technical and commercial aspects primarily drive the development of mobile communication systems and devices. Especially in early stages of technology development, user preferences and values are not adequately considered, which might even have a negative impact on acceptance issues. The aim of this study was the implementation of a quantified understanding of user needs in terms of values into the system design process of cell-phone processors. Moreover, we aimed for an extension of the engineering's trade-off analysis by using conjoint analysis in order to investigate trade-offs between specific device characteristics. Finally, our aim was the evaluation of empirically based user-oriented research methods.

Results of the first study revealed that battery life, speech quality, signal quality and data-transmission rate are the most important device characteristics. Results from conjoint analysis indicated a clear trade-off between battery life and the three other characteristics. Moreover, this research demonstrated that technology acceptance research benefits considerably from an interdisciplinary and multi-method approach. Besides, implementing the users' preferences into early stages of the product development process offers several advantages concerning effectiveness as well as economic aspects of development.

1. Introduction

FACING the continuous improvement and growth of mobile phone networks, the demand for technical developments in the area of mobile devices rises as well. Since mobile internet is accessible via mobile or smartphone, a multitude of services and applications has been developed and is used by a growing number of users (Cisco visual networking index, 2012). Technical improvements and changing user demands require a higher performance of mobile devices, which, in turn, require new and more powerful system architecture designs. Additionally, short technical life cycles and growing market pressure demand fast and customer tailored solutions.

There are many options to improve today's mobile systems. One of the main optimization targets in mobile system design is throughput, e.g. Universal Mobile Telecommunications System (UMTS) towards UMTS LTE (Long Term Evolution). Furthermore, system designers can choose algorithms for implementation that enhance the connection stability in certain environments (e.g. high velocity). If, for example, a mobile phone user is in an area with weak radio signals or he is travelling with high velocity, algorithms could improve the connection stability. On the other hand, such algorithms increase the computational load of the system, which directly leads to higher energy dissipation. This has to be taken into account during the system design process.

2. Background and theory

2.1. System design process

The typical system design process starts with the design phase, where requirements or characteristics are specified, which are supposed to be implemented in the novel or improved product (Fig. 1) (Blanchard & Fabrycky, 2006). For processors of cellular phones the specification is usually focused on application and cost, whereas design cost and power consumption are the biggest challenges for chip designers. While a design option may be used to increase performance, it usually comes at an energy cost or even in terms of increased chip size (higher production costs). For example, high throughput and low energy dissipation are contradicting optimization targets (Fig. 2). The system designer, therefore, has to select the technical parameters to focus on and, in a second step, the task of the designer is to find a solution that best achieves the design goals.

In general, items such as cost, speed and flexibility, as well as power and optimization, all have to be considered. In addition, be-

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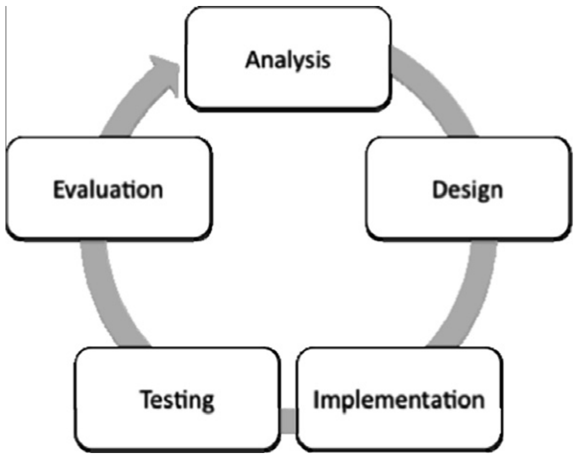

Fig. 1. System design lifecycle (Blanchard & Fabrycky, 2006).

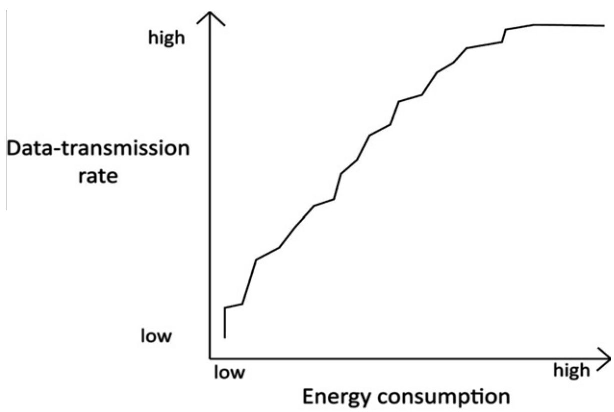

Fig. 2. Example of the contradicting relation between throughput and energy dissipation.

sides power consumption constraints also design costs have to be considered during such trade-off decisions (Chattopadhyay et al., 2006). Thus, determining the best solution for energy as well as for performance of a processor in complex applications, such as cellular phones, is a challenging task for design engineers. Although in practice, the engineers' trade-off decision is purely driven by technical and financial constraints, users of (future) cellular phones might have another weighting of importance of the design options. It might for example be that users do not care whether they have to charge their device several times or at least once per day. Hence, the engineers' trade-off decision could be extended by the input of potential users in early stages of system development.

In practice, most technology-driven companies have installed organizational processes that facilitate the assessment and integration of customer requirement information. This knowledge about user preferences is usually incorporated in the testing phase at the end of the system design process (Eliashberg, Lilien, & Rao, 1997). Typically, the user is asked to evaluate the product in user tests or – in the end – on the shop floor, when the user decides to buy a product (or not). However, in these late stages of the system design cycle, the design process of the product is usually finished and only marginal changes are made in the product when it fails in user tests. Contrary to that, the inclusion of user preferences in early stages of system design, i.e. in the analysis or design phase, could provide a valuable contribution to design trade-offs and lead to different design decisions.

Therefore, the focus of this work is to present a methodology to include user preferences into early stages of the system design cycle. More specifically, we aim for an extension of the engineering trade-off analysis by integrating user preference information in the analysis and design phase of system development.

2.2. Technology acceptance

The integration of user preferences into the system design process leads to another important aspect with regard to system development: user acceptance. The ongoing technical improvements of mobile or smartphones do not automatically guarantee user acceptance. Especially in early stages of system design, user preferences and demands are not adequately considered so far, which might have negative impact on acceptance issues.

There are many examples of failed market launches of technical innovations due to a lack of user acceptance. One example is "Interactive TV" (iTV), which was predicted to be a technical revolution (Stipp, 2001), has not achieved a breakthrough so far. A review of acceptance studies of iTV revealed that user acceptance was only integrated in terms of usability tests of the final product (Bernhaupt, Obrist, & Tscheligi, 2007).

In order to explain and predict the adoption of technologies by end-users and to avoid market failures, several theoretical models were developed. The most influential and best-established theoretical approach is the Technology acceptance model (TAM (Davis, 1989)). The TAM is based on the Theory of Reasoned Action (TRA (Fishbein & Ajzen, 1975)), which originates from social psychology and seeks to explain behavior. The TRA assumes that a person's behavior is influenced by the specific intention to perform a behavior. Further influential factors on this behavioral intention are an individuals' attitude towards the behavior and individual norms. The Technology acceptance model broadened and transferred the TRA assumptions to the area of technical systems. The TAM assumes that the decision to use a new technical system or device is determined by a behavioral intention, which is influenced by the perceived ease of use and the perceived usefulness of the system. The ease of use describes "the degree to which a person believes that using a particular system would be free from effort", the perceived ease of use is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989). In the extended version of the TAM (Venkatesh & Davis, 2000) the model was complemented by external variables, which were assumed to influence the behavioral intention to use a system, e.g. social and cognitive processes (subjective norm, system image and relevance, quality of output). The TAM received considerable attention and was intensively researched and validated (e.g. Davis, 1989; Taylor & Todd, 1995). It was empirically tested using different models or incorporated model constructs (Davis, Bagozzi, & Warshaw, 1989; Gefen, 2004; Taylor & Todd, 1995), user groups (Arning & Ziefle, 2007; Straub, Keil, & Brenner, 1997), and technologies (Featherman & Pavlou, 2003; Hu, Chau, Shen, & Yan Tam, 1999). Summarizing the findings, the TAM was proven as a valid, robust and powerful theoretical model (Davis, 1989; King & He, 2006).

However, the transfer of these acceptance models to the system development process causes some problems:

(1) Acceptance models such as the TAM aim for an evaluation of *complete* technical systems or applications (e.g. online banking, mail systems, WAP services). They do not provide information about the evaluation of single technical characteristics of a product (e.g. display size or battery life time of a mobile device).
(2) Methodologically, the TAM and its model extensions use a structural equation modeling approach to investigate relationships among the proposed determinants of acceptance. The determinants of acceptance models – such as "perceived