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# Design Guidelines and Design Patterns for Ubiquitous Computing

## Matthias Kranz

Research Group Embedded Interaction  
University of Munich  
Amalienstrasse 17  
80333 Munich  
+49 89 2180 4656  
matthias@hcilab.org  
<http://www.hcilab.org/matthias/>

PhD-Supervision: **Albrecht Schmidt**



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## Abstract

Design patterns and guidelines greatly help to facilitate the software development process, e.g. in object-oriented software engineering. Little research so far has focused on applying these powerful methods to application development in ubiquitous and pervasive computing. As for many other methods, e.g. from traditional GUI design, not all patterns apply to the young research area of ubiquitous computing. Also, novel patterns like context-sensitive I/O emerge. My research focuses therefore on design guidelines and design patterns for ubiquitous computing.

## Keywords

Ubiquitous Computing, System Architecture, Design Process, Design Patterns, Development Guidelines, Design Guidelines

## Problem Statement and Research Question

The motivation for my research is to improve the development process and the overall system quality of systems and applications in the field of ubiquitous and pervasive computing. This will, hopefully, result in more deployed real-world installations, which, if these systems prove successful, will implicitly find their way into everyday homes. This opens new markets and business opportunities for commercial products of the

conducted and applied research in this young field in computer science.

'A pattern is the abstraction from a concrete form which keeps recurring in specific non-arbitrary contexts' [1]. Design patterns have proved to be a valuable help and tool for system developers, especially in object-oriented software engineering. Patterns provide solutions to recurring problems and enable the reuse of existing knowledge. This prevents engineers, developers and designer from reinventing the wheel all over again.

Ubiquitous and pervasive computing are relatively young research areas in computer science. Though, a lot of research on application potentials and demonstrators has been done recently, formal approaches have only been investigated with specific focuses so far, e.g. privacy or security. General research on software engineering issues like architectures, middleware and communication have not resulted into a commonly agreed on answer so far.

My research focus therefore concentrates on design guidelines and design patterns for ubiquitous and pervasive computing. This will especially include the following research questions:

- How can methods from software engineering be applied to ubiquitous computing?
- Which design guidelines and design patterns can be applied and which have to be modified?
- Which new design guidelines and design patterns emerge in the context of ubiquitous and pervasive computing? This will comprise

the whole development cycle from an initial idea to the evaluation of the deployed system.

- Which design and development issues are crucial for a successful real-world deployment of a ubiquitous computing project? Clarifying on this question should help to produce more successfully deployed systems.

From other recent research it is known that methods e.g. for system evaluation do not apply because of the nature of ubiquitous computing applications like the distribution and number of interaction interfaces [5]. Novel design patterns like context-sensitive I/O are unknown in standard software engineering [2]. This is the result of the properties specific to ubiquitous computing systems as for example the huge number of involved devices and the different input and output modalities.

The goal of this research is to discover and validate existing and novel design guidelines and design patterns. The advantages of using formal software engineering methods throughout the complete development cycle of a ubiquitous computing project is expected to result in more and better applications that can break the barrier from a lab-only systems to successfully deployed real world systems which are more suited and tailored to the needs of all involved stakeholders.

### **Approach and Methodology**

So far, no general analysis of presented architectures has been conducted to find similarities. Most presented middlewares and frameworks are rarely used in more than one project or by other research groups.

Initial research on design patterns has focused on commercial products, not on research projects [2]. Therefore, my research will start by an analysis of recent research projects to discover the key aspects for their success from a software engineering perspective.

During my research, several smaller and larger ubiquitous computing projects have been developed and deployed. This knowledge will be used as a basis for analysis and comparison against other research. My research in e.g. the larger projects on the Display Cube or on computer-augmented pieces of sports equipment will serve as a solid basis.

As of now, only little research has been done on software engineering issues related to design patterns and guidelines. Published work mostly focuses only on small aspects like privacy or evaluation [5].

By analyzing existing successful ubiquitous computing applications, I hope to be able to discover emerging patterns and key factors for their success. Incorporating this knowledge into my own research projects will enable me to validate and verify the found patterns and guidelines with first-hand knowledge. This will also include the participation in research projects primarily done by other research groups. This kind of external view on ongoing projects will help me to take the necessary step back from my own research and to gain a more objective view on my research.

### **Related Work**

The initial publications on patterns and pre-patterns [2] present a large number of emerging pre-patterns for ubiquitous computing. The authors called their patterns pre-patterns because they are still emerging and are

not in common use yet. By my research, I hope to be able to extend this work to develop a first catalogue of stable patterns and to verify their validity in my research projects. As the authors did not continue their work published in 2004, I will as a first step, update their pattern catalogue with current research projects employing their pre-patterns.

Banavar and Bernstein present a comprehensive scenario of how ubiquitous computing could interweave in our life [3]. By their scenario they identify a great number of application design and architectural challenges. This analysis is a good starting point for identifying necessary patterns for ubiquitous computing development.

Roman et. al. [6] describe their experiences gained from building a ubiquitous computing infrastructure over a three year period. In this environment, they build a great number of applications. From this, they identified six design patterns for ubiquitous computing that were required by all applications. These patterns were multi-device utilization, user-centrism, run-time adaptation, mobility, context-sensitivity and ubiquitous computing environment independence. Some of these patterns have already been identified in [2], like context-sensitive I/O.

The results of the related work revisited show the necessity for a deeper research in design patterns specifically suited towards ubiquitous and pervasive computing.

### **Preliminary Results**

My initial publications on my Ph.D. research topic up to now were focused on smart object systems and the

development of ubiquitous computing infrastructure by extending, modifying and hacking existing commercial off the shelf hardware. Results showed that these approaches are a successful way of speeding up and facilitating the development process itself and that the appliances that came out by applying this process are more usable.

### **Conclusions and Future Steps**

Patterns in general are an appropriate means of reusing previously gained knowledge and facilitate the development process. Patterns research in ubiquitous computing is still in a very early stage. Continuing research in this direction promises to help application developers to faster built better applications in this research area.

The next steps of my research include an analysis of recent projects to identify and validate appropriate patterns. By analyzing existing design patterns and design guidelines e.g. for object-oriented software engineering, HCI and user interfaces, like the Mac OS X, I hope to develop the necessary expertise and familiarity for patterns in general. From this, I hope to be able to develop a hierarchical pattern language for ubiquitous computing.

To validate the results of this work, I will on the one hand employ the developed knowledge in own ubiquitous computing projects, and on the other hand participate in research projects conducted by other research groups. I especially look forward to contribute my knowledge to the intelligent environment research of Prof. Beetz of University of Technology, Munich.

A three months stay at a second institution as visiting researcher would enable me to again validate my research and finalize the to-be-developed patterns and guidelines for ubiquitous computing.

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