A Methodology for Content-Centered Design of Ambient Environments

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Abstract. The design of ambient environments does not depend on technical issues exclusively but also on social aspects. There are several design specifications for ambient environments as well as development principles for the design of such systems, a design method should address. In this paper, we survey design methodologies considering the fulfilling of the design principles and their applicability for ambient environments. Because unprecedented, we introduce a methodology for *Content-Centered Design of Ambient Environments (CoDesA)* and apply this method in parts to an ambient bath environment.

Keywords: Design Method, Ambient Environment, Pre-Artifact, Narrative.

1 Introduction

Designing ambient environments affects several scopes of computer science and research on information systems. Chalmers et al. [1] define three distinct perspectives that have to be converged and blended within ambient environments: experience, engineering and theoretical perspective. An ambient environment should be designed based on a design method embedded in a design theory. To ensure the linkage of the emerging artefacts with real world situations and their users, appropriate experience-based approaches and evaluation cycles have to be applied. We itemized three scopes of design specifications for ambient environments: Physical Environment, Technology and Human. There are various design methods for information systems that examine the aspects Technology and Human but none of them integrates the perspective of the Physical Environment. We assume that the consideration of the physical environment is essential for designing ambient environments successfully. New ambient technologies have to be integrated into established business or home organization structures [2]. As derived from ethnographic studies, these technologies should be linked with other existing media such as paper and telephone at spots where media in general build clusters, for instance the phone shelf. In this sense, the integration of new technologies into home environments should represent the extension of current business or home "systems" by adding hardware devices and software

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agents for supporting intelligence [3,4]. To realize a seamless integration of intelligent business and home technologies, they need to be embedded into daily products and should be designed for business or domestic use [5]. In this context, the reliability of intelligent technologies is similar to well-known devices, e.g. a microwave oven, and they have to be easy to understand such as common devices in current homes. Furthermore, ambient technologies should enable the access to computing resources within and outside of time and places that are traditionally reserved for access of them [6]. Because no adequate design methodology for ambient environments exists, we introduce a methodology for *Content-Centered Design of Ambient Environments (CoDesA)* which considers the physical environment, technological aspects and the prospective users. Our design method is developed and applied in various AmI development projects for different domains, such as well-being, healthcare and shopping.

Next, we discuss existing design methodologies concerning their applicability for the design of ambient environments against several development principles. Then, we describe all required steps of CoDesA in Section 3 and illustrate them to that extent the current state of the ambient bathroom project allows. Thereafter, we exemplify the fulfillment of the aforementioned development principles by CoDesA in Section 4 and conclude this work with a summary and future work (Section 5).

2 Existing Design Methodologies

According to Walls et al. [7], a design process deals with three components: a design method, kernel theories and design process hypotheses. A design method "describes procedure(s) for artifact construction" (ibid., p. 43) whereas kernel theories from the natural or social sciences inform the design method. Last, design processes have to result in testable design process hypotheses, for example, theorems or proofs. A good design of an information system is not only concerned with technically issues but also with managerial ones that affect organizations and their individuals as stated by Markus & Keil [8]: "What developers think makes a good system - it works, it's technically elegant, and it's easy to use - is not necessarily what makes people want to use it - a good fit with their natural incentives and motivation" (ibid., p. 18). In this sense, there exist several development principles towards the design of information systems a design method should address:

- **Principle 1:** The evolving information system has to be "linked" with aspects of its usage within the real world [8,7], e.g., based on the specification of requirements, use cases and scenarios.
- **Principle 2:** A design method has to integrate diverse design steps and stakeholders (e.g. users, professionals) into the development [8,9,7], for instance, by means of creativity workshops with domain experts or users.
- **Principle 3:** A method should grant the option of discussions about diverse design proposals [8,7], e.g., supported by feedback loops.

- **Principle 4:** Concepts and prototypes have to be evaluated, in particular, after the implementation [8,7].
- **Principle 5:** System designs should be emphasized [8,9,7] and represented in a formalized way.
- **Principle 6:** A design method has to forward the development of functional (rapid) prototypes and their iteration [9,7], which enables the integration of feedback within the development.
- **Principle 7:** A method should represent guidance through a dialectic development process [9,7] in all design steps.

The principles can be assigned to several scopes, namely user requirements that are derived from kernel theories (principle 1), principles governing the development process (principles 2,3,6 and 7) and principles governing the design of a system (principle 4 and 5) [9,7].

According to Pries-Heje & Baskerville [10], we analyzed and compared diverse design methods concerning the seven principles and their applicability for ambient environments. We therefore derived a design method pattern that consists of five generalized phases from leading design science approaches [11,12,13,14,15]: (1) identification of problem and needs, (2) design of solution based on scenarios, use cases or requirements, (3) development of solution, (4) evaluation of solution, and (5) specification of a design theory. Based on this generalized structure of a design method, we were able to compare these design methods with regard to their composition and coverage.

In the following we discuss design methods that are relevant for our work. Taylor & Swan [2] specify use cases of ubiquitous systems based on interviews with stakeholders whereas Ross & Keyson [16] try to "sculpt" atmospheres based on the methodological development of design principles for tangible interaction. A Focus Group method is applied by Le Rouge & Niederman [17] for designing public health knowledge management architecture designs. Crabtree & Rodden [4] use ethnographic inquiries for studying routine work at home. Then, they derive requirements the development of ambient systems. For the design and development of domestic ubiquitous computing applications, Schmidt et al. [18] apply a multi-techniques investigation which combines methods of contextual inquiry, cultural probes, technology probes, scenarios-based participatory design and interviews in a qualitative research approach. Perrone et al. [19] define a stakeholder-centered approach for a conceptual modeling of communication-intensive applications that distinguish between problem and solution domains. The Interactive Scenario method is defined by Stroemberg et al. [20] as a promising tool for an early concept definition phase that increases participation of potential users in early stages of a concept design. "The interactive scenario method including improvisation and user acting seems to be very suitable for early-phase concept definition of complex systems that require *"off the desktop"* kind of activity (i.e. ubiquitous computing especially)" (ibid., p. 7). A different aspect is focused by a design method, called Interactive Thread [21]. This design method helps gathering detailed and contextualized data from a large user population while sharing interaction design methods with professional designers

from different disciplines. Maiden et al. [22] present RESCUE, a scenario-driven requirements engineering process that integrates creativity techniques with different types of use cases and system context modeling. Buur et al. [23] wants to solve problems with the potential users rather than for the users. In this way the participants become part of the research process and contribute to the results through feedback and discussions. They combine two design methods that set the focus on skilled actions in the design of tangible user interaction - the Hands-Only Scenario and Video Action Wall. Chung et al. [24] developed a method for designing an initial and emerging pattern language for ubiquitous computing, consisting of pre-patterns describing application genres, physical-virtual spaces, interaction and techniques for managing privacy, and technologies for fluid interactions. Finally, Essence is a creativity method for software development that is based "on principles similar to role-playing games and improvisational theater" ([25], p. 549). The design method "melds creative sessions into agile development to employ development speed and flexibility throughout the project" (ibid.). Essence focuses on People, Product, Process and Project in each process step. Tab. 1 provides a survey of the analyzed design methods concerning the seven development principles for the design of information systems. Almost all considered design methods contain a step for specification of requirements, use

Table 1. Analyzed design methods concerning the seven principles for developing information systems

	Principle 1	Principle 2	Principle 3	Principle 4	Principle 5	Principle 6	Principle 7
Taylor & Swan [2]	•	•	n/a	-	-	-	-
Ross & Keyson [16]	•	○	n/a	•	-	-	•
Le Rouge & Niederman [17]	•	•	•	-	•	-	○
Crabtree & Rodden [4]	•	•	n/a	-	-	-	-
Schmidt et al. [18]	•	•	○	-	•	•	○
Perrone et al. [19]	•	•	○	-	•	•	○
Strömberg et al. [20]	•	•	n/a	-	-	-	-
Mackay [21]	•	○	n/a	-	-	-	-
Maiden et al. [22]	•	•	•	-	-	-	-
Buur et al. [23]	•	•	•	-	-	-	-
Chung et al. [24]	-	-	•	•	-	-	○
Aaen [25]	n/a	n/a	n/a	n/a	n/a	n/a	○

(• =Complete; ○ =Partly; - =No match; n/a =Not applicable)

cases etc. Similarly, the majority integrates diverse stakeholders such as users or experts, for instance, via creativity workshops. By contrast, only half of the methods provide guidance with the integration of results of discussions and evaluations of prototypes into the further development in the sense of feedback loops. In this context, only the methods of Ross & Keyson [16] and Chung et al. [24] cover a dedicated evaluation phase. Furthermore, only a few of the design methods focus on a formalization of the results within the implementation phase. Hence, the development of mock-ups or rapid prototypes to get early feedback in rapid evaluation cycles is a marginal phenomenon. In summary, none of the considered design methods fulfills all development principles for the design of information systems and thus, we describe our methodology in the next section.

3 A Methodology for the Design of Ambient Environments

Based on the literature review in Section 2, we identified seven development principles for the design of information systems. We analyzed existing design methods with regard to these principles, but none of these methods fulfills all development principles for the design of information systems. We therefore developed a *Methodology for Content-Centered Design of Ambient Environments (CoDesA)* (cf. Fig. 1). Our methodology consists of four phases: *Identification of Problem & Needs, Design of Solution, Development of Solution* and *Evaluation of Solution*. The latter phase includes also the *Specification of a Design Theory*. This structure is related to the method pattern that we have derived from prior design science research in information systems [11,12,13,14,15]. The four phases of CoDesA cover nine tasks. The methodology is elaborated in the next sections and specific inputs, outputs and involved stakeholders are provided for each task. Here, we present results for Tasks 1 to 4. Other tasks are target of our current research.

3.1 Identification of Problem and Needs

According to the aforementioned method pattern in Section 2, this phase targets the awareness of a problem and identification of the motivation to design a solution [13,14,15].

Task 1 - Identification of Problem and Needs. The objectives of this task are to identify the (business or private) problems and needs and to derive requirements for the expected solution. In this task, workshops with domain experts are conducted to identify a problem that has to be solved by the application of CoDesA and the resulting solution.

Consistent with the principles of Ambient Intelligence, we intend to integrate contents and information technology into a physical environment. The use case of an ambient bathroom represents a "far out" vision for direct user interactions with contents, and combines advanced content and knowledge management with

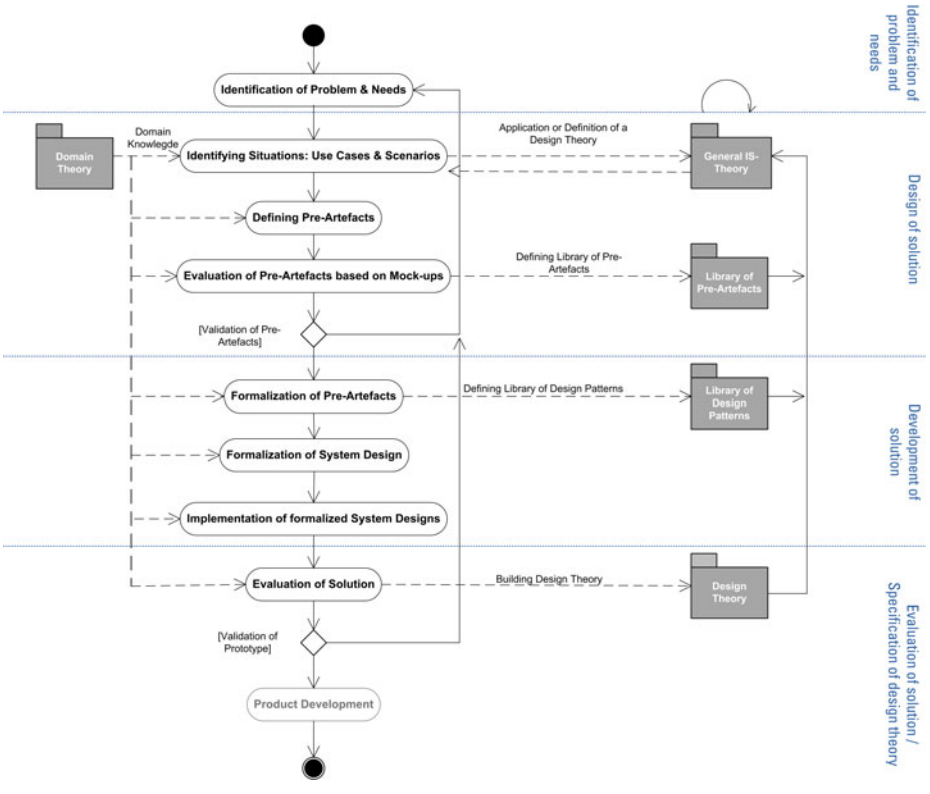


Fig. 1. Methodology for Content-Centered Design of Ambient Environments (CoDesA)

an Ambient Intelligence scenario and the Internet of Things - in a place which everybody is familiar with - the bathroom. In that use case, we want to show how users can interact with contents in physical environments in a way that leaves the dimension of "small windows to the infosphere".
Involved stakeholders: Domain experts and computer scientists
Input: -
Output: Description of (business or private) problems and/or needs

3.2 Design of Solution

In the second phase of CoDesA, solutions to meet the problems or to satisfy needs are specified through scenarios, use cases or requirements. Creativity workshops with different stakeholders are required [11,12,13,14,15].

Task 2 - Identifying Situations: Use Cases & Scenarios. This task focusses on the specification of situations in the domain of interest according to the problems and needs. More precisely, situations that address the defined problems or satisfy the needs are specified together with domain experts in creativity

workshops. Situations are textual descriptions of different entities (objects, roles, information, background environments and services), which perform particular activities and interact with each other. These entities represent characteristic features of a corresponding class of situations within a domain, e.g., shopping situations. Thus, situations resemble frames [26], schemas [27], and use cases. The application of a domain theory integrates domain-specific common sense into the process of specification. A general IS theory constitutes the frame for the analysis of situations. In the case, that there exists no appropriate theory, a general IS theory can be defined incrementally during the application of CoDesA. In our case, we held a creativity workshop with a leading manufacturer of high-quality bathroom equipment. With the help of several creativity techniques, situations, or more precisely *narratives* have been specified according to the question: "Where and in which way do we face information and media in our daily life?" The results were transformed into a textual description, for instance:

> *"Anna gets site-specific weather information when she is brushing her teeth in the bathroom. Based on weather information and her calendar, free-time event suggestions are given, e.g. "Today, 8 p.m. - Sneak Preview at CinemaOne. Do you want to order tickets?"*

Involved stakeholders: Domain experts and computer scientists
Input: Description of (business or private) problems and/or needs
Output: Specification of situations in form of narratives, graphics or other non-formal descriptions

Task 3 - Defining Pre-Artifacts. The objective of this task is the transformation of the identified narratives into semi-formal structures, i.e. *Pre-Artifacts*. Pre-Artifacts are semi-formal perspectives of the narratives, i.e. the situations, and highlight the essential elements of each narrative [28]. There are two alternatives for deducing a Pre-Artifact from a narrative: (a) extraction of the essential concepts by means of a general IS theory and a domain theory, or (b) in the case, that there exists no appropriate IS theory, the narrative has to be analyzed according to several steps that will be elaborated in the following. The domain theory constitutes a frame for the process. Following case (b), there are five steps to deduce a Pre-Artifact from a narrative.

1. **Extraction of terms according to the Abstract Information Systems Model (AISM).** *AISM* [29] describes situations in ambient environments in form of generic concepts. Each narrative has to be analyzed concerning several aspects. *Agents* take specific *Roles* within a situation. *Services* provide *Information* that can be used by *Agents*. *Agents* and *Services* have specific intentions to participate in a situation. *Information* has several realizations, e.g., image, text, video. Communication takes place between *Service* and *Service, Service* and *Agent* as well as *Agent* and *Agent* in a specific context.
2. **Assignment of terms to categories.** The extracted terms have to be assigned to the essential categories of AISM: Agents & Roles, Information

and Services. The derivation of *Competency Questions* [30] for each term enables a later validation of the Pre-Artifact.

3. **Description of concepts and their relations.** Within this step, the categorized terms of the narrative and their relations have to be represented in AISM. This step covers the proper definition of each Pre-Artifact. It describes conceptual entities and their relations that are key elements within the narrative.
4. **Description of Pre-Artifacts.** As part of the library of Pre-Artifacts, the resulting Pre-Artifact has to be described according to a specific structure. The description consists of several components, for instance information and their realizations; goals, i.e. intentions of services or agents; roles and conditions; services etc. (cf. Tab. 3)
5. **Validation of Pre-Artifacts.** The quality and coverage of the Pre-Artifact can be evaluated by means of the defined Competency Questions. In the case that some questions cannot be answered, steps 1-5 have to be repeated.

In our bathroom project, we followed option (b) because of the absence of a general IS theory. Before we started to define Pre-Artifacts, we asked 46 potential early adopters of ambient bath environments, i.e. technical-savvy graduates, to rate the ten narratives which resulted from Task 2. This pretest was done in order to identify only those situations that are relevant from an end-user perspective. Therefore, on a seven-point Likert-scale ranging from strongly disagree (1) to strongly agree (7) and consistent with the compatibility measure of Moore and Benbasat [31] subjects had to indicate the degree to which each situation fits into their personal life. Results indicate that Narratives 1, 6 and 10 (see Appendix A) performed best with average values of 5.0, 5.1 and 5.3. Further, all of these ratings lie all significantly above the neutral test value of 4 by conducting a one-sample t-test. Based on the resulting three narratives, we defined the corresponding Pre-Artifacts. In the current work, we will describe this process for Narrative 1 (see Task 2). After the analysis of the narrative and extraction of the terms, we assigned them to the essential categories that are provided in Table 2. Furthermore, we derived the following Competency Questions:

- *Who is Anna?*
- *How is the weather in CityX today?*
- *Whats going on today?*
- *Where is Anna's calendar?*
- *In which format are the events for today available?*
- *Who is the ContentProviderX?*
- *What is the day of the week?*
- *Where is Anna?*

In a next step, we modeled the concepts and their relations according to AISM graphically and described the Pre-Artifact based on the structure that is shown in Tab. 3. Finally, we validated the Pre-Artifact by answering the Competency Questions successfully.

Table 2. Categorized Terms of Narrative 1

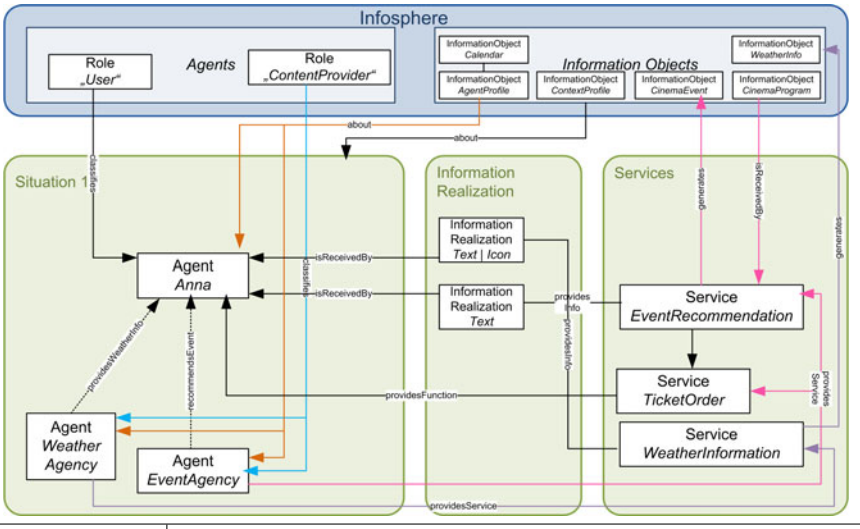
Agents & Roles	Information	Services
Anna (Role: User)	Weather information	WeatherInformation
	Cinema event information	EventRecommendation
	Cinema program	TicketOrder
	Anna's calendar	
	Day of week	
	Time	
	Location	

Involved stakeholders: Ontologists, IS engineer
Input: Specification of situations in form of narratives, graphics or other non-formal descriptions
Output: Representation of narratives in form of semi-formal Pre-Artifacts

Task 4 - Evaluation of Pre-Artifacts Based on Mock-ups. In this task, narratives in form of semi-formal Pre-Artifacts are evaluated with the objective to generate preliminary implications regarding user acceptance and marketing strategies. Because we are in the domain of ambient environments, we evaluate the narratives with the help of mock-ups at this early stage of the development process. Based on the Technology Acceptance Model and the more marketing-related work of Kamis et al. [32], perceived characteristics of the information and communication services of these narratives are measured, namely expected usefulness, intention to use and intention to subscribe. We focus on the services as such, because there is no concrete information available by this mock-up bases approach. Based on the results of the evaluation, domain experts are able to discuss the narratives more in detail and thus, are able to skip narratives that are not relevant any more. Further, if the analysis of the evaluation results is negative at all, Tasks 1 to 4 have to be repeated.

In the our project, we exemplify this task with the three information and communication services of Narrative 1 as shown in Tab. 3. We adopted the TAM measures from Wixom and Todd [33] and adapted the intention to subscribe measure from the purchase construct described by Kamis et. al [32]. Thirty-three technical-savvy subjects, i.e. potential early adopters, participated in this evaluation. Each narrative was presented with the help of dolls, a mock-up, i.e. a midget bathroom, and a slide show that exemplified the services (cf. Fig. 2). After each narrative was presented, the participants had to rate the services according to the measures on 7-point Likert-scales ranging from strongly disagree (1) to strongly agree (7). Results show that expected usefulness (3 items, Alpha=.93), intention to use and intention to subscribe for a monthly fee have average scores of 4.1, 5.5 and 2.7 for the Weather Information Service, 3.7, 4.8 and 2.9 for the Event Recommendation Service and 3.5, 4.0 as well as 2.4 for the Ticket Order Service. Thus, domain experts would rather focus on the weather information service due to the relative high user acceptance ratings but all of the services should be made available for free as the intention to subscribe for a monthly fee was perceived

Table 3. Pre-Artifact based on Narrative 1



Narrative	*It's Thursday morning. Anna gets site-specific weather information when she is brushing her teeth in the bathroom. Based on weather information and her calendar, free-time event suggestions are given, e.g. "Today, 8 p.m. - Sneak Preview at CinemaOne. Do you want to order tickets?"*
Information	Calendar of Anna; AgentProfile of Anna; AgentProfile of EventAgency; AgentProfile of WeatherAgency; ContextProfile of Situation; CinemaProgram; CinemaEvent (InformationRealization.Text); WeatherInfo (InformationRealization.Text / InformationRealization.Icon)
Goals	Extract: (a) Informing the user about the weather in New York (b) Informing the user about potential events today (c) Enabling the user to know how to order tickets for events
Roles & Conditions	*User* (Condition for role: Agent is authorized for using bathroom); *ContentProvider* (Condition for role: Agent is authorized for providing content in bathroom)
Services	EventRecommendation; TicketOrder; WeatherInformation
Types of Communication	– *(A) Agent.EventAgency ⟶ Agent.Anna (unidirectional) (symbolic)* – *(B) Agent.WeatherAgency ⟶ Agent.Anna (unidirectional) (symbolic)* – (C) Service.EventRecommendation ⟶ Service.TicketOrder (unidirectional) – (D) Service.EventRecommendation ⟶ Agent.Anna (unidirectional) – (E) Service.TicketOrder ⟶ Agent.Anna (unidirectional) – (F) Service.WeatherAgency ⟶ Agent.Anna (unidirectional) – Synchronal: D AND E – Asynchronous: C AND(D AND E) AND F
Competency Questions	Extract: – Who is Anna? – How is the weather in New York today? – Whats going on today? – Where is Anna's calendar?

Fig. 2. Mock-up-based Evaluation of Pre-Artifacts

significantly negative at the .001 level when conducting a t-test with 4 being the neutral test-value.
Involved stakeholders: Potential early adopters of ambient bath environments, domain experts
Input: Representation of narratives in form of semi-formal Pre-Artifacts
Output: Preliminary implications for Pre-Artifacts regarding user acceptance and marketing strategies

3.3 Development of Solution

The solution consists of a library with evaluated Pre-Artifacts, i.e. semi-formal structures of the identified narratives. In this phase, the defined Pre-Artifacts have to be transformed into an ontological structure. These formalized structures will be stored in a library of design patterns. Based on these design patterns, requirements and a formalized system design can be derived. Furthermore, the formalized system design is implemented as service architecture [15,13]. This phase of CoDesA will be applied in the second and third year of the bathroom project; therefore, we exemplify the following tasks without actual results. In this contribution, we will rather give a rough idea of the development of the solution.

Task 5 - Formalization of Pre-Artifacts. The objective of this task is to formalize the semi-formal Pre-Artifacts in order to derive processable design patterns and specifications. Christopher Alexander introduced the term "design pattern" for shared guidelines that help to solve architectural design problems [34]. Later, the potential for reusing ontological structures through a pattern-based approach was investigated [35,36]. There are several opportunities to formalize the identified Pre-Artifacts, for instance, their transformation into Prototypical Ontology Design Patterns (PODPs) [28] that are derived and formally modeled by reusing Ontology Design Patterns (ODPs) grounded in DOLCE [36]. Furthermore, a formalization based on UML is conceivable. Both possibilities enable the specification of requirements and components for the final system design.
Involved stakeholders: Computer scientists and ontologists
Input: Representation of narratives in form of semi-formal Pre-Artifacts (library of Pre-Artifacts)
Output: Formalized representation of Pre-Artifacts (library of design patterns)

Task 6 - Formalization of System Design. This task focusses on the specification of the formalized system design. It covers supporting architectures, data and service infrastructures. The system design is formalized based on the library of design patterns. Furthermore, the design of the later implementation is completed with adequate architectures (e.g. Service Oriented Architectures (SOA), RESTFul) and data infrastructures, for instance, persistence layers of ontology repositories.
Involved stakeholders: Computer scientists
Input: Library of design patterns
Output: Specification of formalized system design

Task 7 - Implementation of Formalized System Designs. Here, the formalized system design is transformed into machine-processible code. Thereafter, this code has to be linked with the hardware components integrated in the physical environment. As a result, the prototype of the ambient environment is finalized.
Involved stakeholders: Computer scientists
Input: Specification of formalized system design
Output: Prototype of an ambient environment

3.4 Evaluation of Solution and Specification of Design Theory

In the last phase, the prototypical ambient environment has to be evaluated empirically. As a result, design theories can be developed or further specified [11,12,13,14,15]. At the same time, the evaluated prototype constitutes the basis for a deployment in real life - the product development in the free economy. This phase of CoDesA will also be applied in the third year of the bathroom project.

Task 8 - Evaluation of Solution. With the help of an empirical evaluation, the implemented prototype is tested against the requirements specified by the Pre-Artifacts. In case the prototype is not successful, Task 5 to 8 have to be repeated. Learning from the results, design theories can be built up or further specified.
Involved stakeholders: Computer scientists, end users such as information and communication service providers and their customers
Input: Prototype of an ambient environment
Output: Valid ambient environment prototype tested against the specified requirements

Task 9: Product Development. The final task of the method covers the serial production of the evaluated ambient environment prototype in an economic sense by a domain-specific company.
Involved stakeholders: Domain experts
Input: Valid ambient environment prototype tested against the specified requirements
Output: Serial production of the ambient environment

4 Discussion

We proposed seven development principles for the design of information systems in Section 2 and we analyzed several design methods concerning these principles. None of the design methods has fulfilled all development principles. Therefore, we discuss the fulfillment of these principles by CoDesA in the following:

1. The resulting information system is linked to the real world through creativity workshops that are part of CoDesA. The narrative approach ensures further a representation of real world situations. The evaluations are conducted based on physical mock-ups and prototypes. This integrates the concept of physical environments into user studies and grounds the design process in practice outside the scientific world.
2. CoDesA integrates several stakeholders into diverse design steps during the development process, e.g., domain experts, users and ontologists. In this way, diverse prospects, intentions and expertises are integrated into the design process, which defends from "lack of objectivity".
3. Our method provides the option of discussions and iterations after the evaluation Tasks 4 & 8. Depending on the results of the evaluation, a feedback loop can be initiated for reengineering the artefacts of the preceding tasks.
4. CoDesA schedules the evaluation of the identified Pre-Artifacts based on a mock-up (cf. Task 4) as well as the validation of the resulting prototype (cf. Task 8). Furthermore, an additional pretest with end-users can be conducted to rank the defined narratives if required. In summary, CoDesA covers a continuous *build & evaluate cycle* during the whole design process [11].
5. The identified Pre-Artifacts as well as the derived system design are represented in a formalized way and stored in a repository, i.e. the library. This ensures standardization and adequate reusability within further design processes.
6. CoDesA forwards the development of rapid prototypes and their iteration, for instance the development of mock-ups for evaluating the Pre-Artifacts (cf. Task 4). Within the design process, rapid results are generated that can be analyzed for detecting design failures very early.
7. Our method gives guidance during the whole development process in all design steps - from the identification of (business or private) problems and needs to the serial production of the ambient environment. CoDesA accompanies designers of ambient environments beyond the specification of requirements and helps to "pursue the path".

As a limitation of the current work, we could only apply CoDesA to Tasks 1 to 4. We are therefore not able to exemplify results of the other task. This will be part of future work as discussed in the following section.

5 Conclusion and Future Work

A good design of an ambient environment does not depend on technical issues exclusively but also on aspects concerning the human and the physical environment. Ambient Intelligence implies modularized computing environments and

specific interfaces and therefore requires several specifications and development principles for the design of such systems. In this article, we proposed seven development principles for the design of information systems, which should be addressed by a design method [8,9,7]. We further analyzed capabilities of different design methodologies concerning these principles. Because none of the considered design methods fulfilled all development principles, we introduced a new methodology for *Content-Centered Design of Ambient Environments (CoDesA)* which fulfills all the principles. The linkage of the resulting information system with the real world is ensured through the integration of different stakeholders into the design process and through a narrative-based approach that represents real world user interactions. CoDesA forwards the development of rapid prototypes as well as their evaluation. Furthermore, our method gives guidance during the whole development process in all design steps. Currently, we are able to present experiences in applying Task 1-4. The application of further tasks will take place until 2012 as part of the bathroom project.

In our future work, we will therefore proceed with several tasks: (1) ontological formalization of Pre-Artifacts, (2) development and evaluation of a prototype of an intelligent bathroom based on the results the first four tasks, and (3) automatic mapping of Competency Questions, narratives, and terms onto Pre-Artifacts.

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Appendix A: Extract of Identified Narratives (Task 2)

All narratives can be requested from the authors.

- **Narrative 6.** Fortunately, it is weekend. Robert has taken a shower listening to his favorite music. Leaving the bathroom, Anna flits into the room. Robs music has become silent and Anna is welcomed by music from her own music collection. The music starts at the point in the playlist where Anna stopped listening the evening before. After a while, she says Stop music and the song falls silent. Anna wants to see her personal news collage while taking a shower.
- **Narrative 10.** Robert is brushing his teeth in the morning; he listens to the news on the radio. Then, he takes a shower. Now, the news messages are displayed in form of pictures and text at the glass door of the shower.