Designing Ubiquitous Information Systems based on Conceptual Models

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Sabine Janzen, Andreas Filler, Wolfgang Maass

Chair in Information and Service Systems (ISS)
Saarland University, Germany
"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."

(Markus & Keil, 1994)
Heterogeneous design teams of Information Systems (IS):

How to bring the ideas, expertise and needs of all groups together when designing a new IS?

→ Conceptual Models (CMs)

(Wand et al., 1995)
Advantages of the Use of CMs

- **Identification of important concepts and relations**  
  (Markus et al., 2002; Wand et al., 1995)

- **Can be semantically described by shared vocabulary**  
  (Salvatore & Smith, 1995)

- **Logic of a CM can be evaluated and matched with other CMs → important for re-use**  
  (Purao et al., 2003)

- **Abstraction on the situational level in which users and user groups perform activities supported by IS**  
  (Wand et al., 1995)
Additional requirements for **Ubiquitous Information Systems (UIS):**

- **Support for real-world situations, ubiquitous computing technologies anywhere and anytime** *(Lyytinen & Yoo, 2002; Yoo, 2010)*

- **A holistic view of situations is required, in which users and groups interact with each other and with additional services** *(Janzen et al., 2010; Klemmer & Landay, 2009)*

→ **Situational Design Method for Information Systems (SiDIS)**
Situational Design Method for Information Systems (SiDIS)

Tasks

- T1: Identification of problem and needs
- T2: Derivation of situations (narratives)
- T3: Derivation of diagrammatic CMs
- T4: Evaluation of diagrammatic CMs
- T5: Derivation of formal propositional CMs
- T6: Formalization of system design
- T7: Implementation of formalized system design
- T8: Evaluation of solution
- T9: Product development

Phases

- Presentation focus on CMs-related steps

Design of solution

- General IS theory
- Library of diagrammatic CMs

Development of solution

- Defining library of design patterns
- Library of design patterns

Evaluation of solution

- Building design theory
- Design theory

Specification of design theory

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Towards Explicit Domain Knowledge

Implicit domain knowledge
Languages: natural language, ‘language of thought’
→ In particular natural languages

Explicit domain knowledge expressed by a non-formal language
Languages: vocabularies, thesaurus, class diagrams, OWL Light, UML
→ in particular diagrammatic languages

Translation 1

Explicit domain knowledge expressed by a formal language
Languages: OWL-DL, OWL2, OWL-Full, PL1, higher-order PL, non-logical mathematical languages
→ in particular symbolic languages

Translation 2

Individual Conceptual Modeling

Conceptual Modeling

System Design, Implementation, Execution
The 3 Conceptual Models (CM) of SiDIS

(1) Narrative conceptual models of situations
(2) Diagrammatic conceptual models (Pre-Artifacts)
(3) Propositional conceptual models

It’s Thursday morning. Anna gets site-specific weather information when she is brushing her teeth in the bathroom.
How to apply SiDIS to design an Ubiquitous Information System (UIS)?

Exemplary application of SiDIS to develop an „Intelligent Bathroom“ as UIS within the EU project IKS with the industrial partner Duravit (manufacturer of high-end bathroom furniture)
SiDIS – Task 1

Task 1: Identification of problems and needs

What is the problem that shall be solved? What is the motivation to design a solution?

- Identification of (business or private) problems and needs
- Workshops with domain experts to identify problem that has to be solved by the intended solution
Task 2: Derivation of situations (narrative CMs)

Imagine, the intended solution would be already available: How would it be used in everyday life?

- Specification of usage **situations** in the domain of interest according to problems and needs defined together with domain experts
- **Situations** are textual descriptions of different entities - objects, roles, information, environments, services etc. – performing particular activities and interacting with each other
Task 2: Derivation of situations (narrative CMs)

Creativity workshop with Duravit:

- Generation of ideas via Brainwriting Pool method
- Application of situations in real bathroom environment
Application of SiDIS – Task 2

Derivation of narrative CMs based on situations

**Narrative 1**
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. - *Miss Marple Night* at CinemaOne. Do you want to order tickets?"

How to write a narrative within SiDIS?
- Focus on entities of situation (actors, roles, information, environments) and interactions between them
- Instance level → not type level
- No technical or implementatory aspects
- Understandable for everyone
- Short and sweet
Task 3: Derivation of diagrammatic CMs

How to represent narratives in a structured, diagrammatic form?

- Translation of narrative CMs into semi-formal, diagrammatic CMs
- Highlighting essential elements of each narrative

- Representation of narrative CMs in form of semi-formal diagrammatic CMs as **Pre-Artifacts**
Pre-Artifacts (diagrammatic CMs):

- Information System $\rightarrow$ composition of Information Sphere, Social System, Service System (Lamb & Kling, 2003; Lechner & Schmid, 2001; Orlikowski & Barley, 2001)
- UIS $\rightarrow$ additional fourth level: Physical Object System $\rightarrow$ Abstract Information System Model (AISM) (Maass & Janzen, 2011)

- Pre-Artifacts conceive usage situations by highlighting requirements on social structures, information objects, physical objects and services of the UIS
SiDIS – Task 3

Construction of Pre-Artifacts in 5 Steps:

<table>
<thead>
<tr>
<th>Patterns P / Steps</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
<th>Step 5</th>
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</thead>
<tbody>
<tr>
<td>P1: Role Interaction</td>
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<td>P2: Service takes Role</td>
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<td>P3: Service uses Information Object</td>
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<td>P4: Service Interaction</td>
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<td>P5: Role uses Information Object</td>
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<td>P6: Role uses Service</td>
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<td>P7: Role creates Information Object</td>
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</table>

**Step 1:** Definition of Information Objects (IO) in Information Sphere  
**Step 2:** Definition of user-system or user-user interactions related to IO  
**Step 3:** Definition of Roles taken by Services  
**Step 4:** Definition of supporting Internal Services  
**Step 5:** Definition of user initiative
Application of SiDIS – Task 3

It's Thursday morning. I get site-specific weather information when I am brushing my teeth in the bathroom.

Goals
a) Getting weather information for user's location [User]

Notation
- Information Object
- Role
- Interface Service
- Internal Service
- Physical Object

Representations:
- Representation of information objects
- Representation of roles
- Representation of services
- Representation of physical objects
Task 4: Evaluation of diagrammatic CMs

Will services represented in Pre-Artifacts be accepted by future users?

- Pre-Artifacts are evaluated to generate preliminary implications regarding user acceptance
- Usage of mock-ups at early stage of design process
- Focus on information objects delivered by services that are represented in Pre-Artifacts

- Application: Mock-Up based evaluation with 111 subjects from 3 countries to rate the derived situations
Task 5: Derivation of formal propositional CMs

**How can diagrammatic representations of situations be processed by the future system?**

- Translation of Pre-Artifacts into propositional CMs
- Manual, automatic or semi-automatic translation possible
- Creation of specifications for later system designs and machine-processable CMs that can be verified (Wand et al., 1995, Bera et al., 2010)

- Library of formalized design patterns
Use of computational ontologies for conceptual modeling by means of a pattern-based approach (Clark et al., 2000, Gangemi, 2005)

**Pros**
- Web Ontology Language (OWL) is implementable, which means OWL ontologies are machine-readable, and thus computational.
- OWL constructs are independent, i.e. classes can exist independent of instances or properties and properties are independent of classes.
- Verification: OWL allows inferences and automated reasoning support.

**Cons**
- no clear rules how to map from domain information as represented by Pre-Artifacts to OWL constructs similar to the intended propositional CMs
SiDIS – Task 5

Generating propositional CMs in OWL:

- Setup of patterns importing Pre-Artifact Model
- Specification of pattern-specific object properties through inheritance structures
- Definition of sub properties of generic object properties imported from the model
- Super-properties and concepts of Pre-Artifact Model remain unchanged
- Incremental modeling of propositional CM by importing patterns step by step according to the requirements of the Pre-Artifact
- Instantiation of relevant concepts of pattern
Final representation of interface service *Personalized Weather Service*:

```xml
<Model:InterfaceService rdf:about="#PersonalizedWeatherService">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <RoleUsesIO:supportsCreation rdf:resource="#Creation_1"/>
  <RoleUsesIO:interfaceServiceTakesRole rdf:resource="#PersonalizedWeatherAssistant"/>
  <RoleInteraction:supportsR_Interaction rdf:resource="#R_Interaction1"/>
  <ServiceInteraction:finalizesS_Interaction rdf:resource="#S_Interaction_3"/>
  <ServiceInteraction:finalizesS_Interaction rdf:resource="#S_Interaction_4"/>
</Model:InterfaceService>
```
Summary of application of further steps:

**Task 6:** Formalization of system design

**Task 7:** Implementation of formalized system design
- Implementation according to OSGi standard
- 7 IKS Stack/Apache Stanbol components could be reused for the realization of the UIS
- 4 developer teams from Turkey, Italy and Germany

**Task 8:** Evaluation of solution
- 55 subjects have evaluated 6 services in a lab experiment with constructs from Technology Acceptance research (e.g., Davis 1989)
- Subjects had to play through the 3 Situations from SiDIS Task 4
Two-parted knowledge representation:

- Situation
  - Mirror
    - Personalized Weather Assistant
    - Personalized Weather Service
  - Wall
    - Personalized Event Recommendation Service
- Location
  - User
- Events
  - Personalized Music Assistant
- Context
  - Shower
  - Music Collection Service
  - Personalized News Collage Service
- News
  - Music playlist
Implementation of formalized system design:

- Formalized system design is transformed into machine-processible code → modules in system design realized as software components.
- Use of propositional CMs as knowledge models for the physical situation management → *Situational part of KR*
- Information Objects stored as knowledge models for the interaction with the user → *Contextual part of KR*
Wrap-up

- Use of **Conceptual Models (CMs)** for the design of Ubiquitous Information Systems

- Consists of 4 phases covering 9 tasks according to Design Method pattern (Hevner et al., 2004; March & Smith, 1995; Pfeffers et al., 2006; Rossi & Sein, 2003; Kuechler & Vaishnavi, 2008)

- The presented methodology **SiDIS** uses three types of CMs:
  - Narrative CMs of situations
  - Diagrammatic CMs (Pre-Artifacts)
  - Propositional CMs

- Closing gap between qualitative requirements (cf. narratives) and formal, machine-processable structures (cf. propositional CMs)
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