Modeling and Designing User Assistance in Intelligent Environments with the GOAL Method

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Abstract. The design of smart environments remains challenging. Such a system has to provide useful support for its users in everyday situations by keeping the user interface as simple as possible. Shifting the focus from the desktop into everyday life requires a careful analysis of the users' needs with respect to the physical environment, i.e. the building structure and involved artifacts. We believe that current software engineering methods and tools are not sufficient to develop such systems, e.g. UML cannot express spatial context. In this paper, we describe a new design method for intelligent environments that is grounded on Activity Theory and a 3D model. The method suggests a structured procedure to analyze the users' needs, leading to an activity model that aids the designer to focus on useful assistance features. The 3D model supports decisions about the instrumentation of the environment with sensors and actuators.

1 1. The GOAL Method

It is of critical importance for the success of AmI projects to assess and capture the needs of the target group, so that system developers can put themselves in the position of the user. Especially in the domain of Ambient Assisted Living it is difficult for the user interface designer to anticipate the limited (sensory, motor, and cognitive) abilities of elderly users. Typical elicitation techniques include e.g. workshops, ethnographic studies, and interviews (see Capturing Ambient Assisted Living Needs[1] Workshop). These elicitation techniques give rather subjective and anecdotal results. We propose an intermediate step where informal statements are transformed into a structured representation of activities and actions, with references to situational context. Our proposed design method *GOAL* (**G**eometry-**O**ntology-**A**ctivity Mode**L**) is based on three pillars: i) a geometric environment model; ii) an activity model; and iii) an ontology which provides the symbolic names that tie both models together. We ground our design method on a detailed, geometric location model of the actual environment where the assistance system is about to be installed. All elements of the geometric model have

[1] http://workshops.icts.sbg.ac.at/ami2008aal/

M. Tscheligi et al.(Eds.): AmI09 Salzburg, Austria, 2009
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their symbolic counterparts in the ontology. The activity model defines activities that reflect the users' needs and contains references to related artifacts and their locations in the environment model. Activity Theory [1] defines activity as purposeful interaction of a subject with the world. Accordingly, we define:

- An **Activity model** hierarchically structures activities in actions and operations. Activities are directly motivated by the users' needs, whereas actions pursue certain goals towards these needs. Actions include operations that can be carried out without consciousness thought. Artifacts represent tools or signs that mediate cultural knowledge or functionality. Based on these concepts, activity can be modeled as a tree of (subject, artifact, objective) triples.
- A **situational semantic activity model** extends an activity triple with references to the situational context in which the activity is typically performed, with respect to location, time, and human-environment interaction. Such a model can be conceived as a six-tuple of (subject, artifacts, objective, locations, times, instrumentation). All elements refer to an ontology that defines their semantics.

After initially assessing the users' needs with informal methods, the GOAL design method supports interaction design for user assistance in instrumented environments through a situational activity model in the following five steps:

(1) Geometric Location Modeling We have extended YAMAMOTO [2] (**Y**et **A**nother **MA**p deling **TO**olkit) with parametric 3D objects to geometrically model the room layout, including walls, doors, and windows. The room's furnishing, like shelves, cabinets, and tables, can be represented by generic 3D objects, or imported as triangle meshes. Finally, artifacts and appliances, like a dishwasher, can be modeled and placed in or on the furniture.

(2) Creating an ontological environment model In the second step we create a symbolic representation of the domain, which defines a unique symbolic identifier for each artifact and spatial region of the environment model, and also subjects and roles. The goal of this step is twofold: On the one hand, these identifiers shall provide the link between the geometric model and the activity model that is to be created in the third step. On the other hand, in conjunction with literal names, these symbols are particularly suitable to guarantee that a consistent notation will be used throughout the whole development process in the specification and documentation documents. We use the *UbisWorld* Ontology [3] that comprises the *UbisEarth* ontology of geographic places and a physical ontology that describes physical things in the world, including persons and artifacts. *UbisWorld* is multilingual and supports the localization and translation of the system.

(3) Creating a Situated Semantic Activity Model In the third step the users' activities and needs shall be modeled in a situational activity model, as defined above. The goal of this step is to organize and structure the informal requirements gathered by the elicitation techniques of the first phase. The **subject** of the activity/action/operation refers to the actor that performs it. The subject can either be an individual person, or, more generally speaking, a role like "user", "care giver", or "care taker". According to AT, **artifacts** act as a mediator between subject and objects (e.g. a remote control is used to watch TV). Hence we model all necessary artifacts as 3D objects in the geometric environment model and also as physical elements in the ontology. The **needs** (objectives) of the subject are represented as verbose descriptions. The **locations** where the activity is typically performed are given through references to the geometric environment model. The **times** specify when an activity is typically performed, e.g. breakfast in the morning.

(4) Interaction Design The activity model of step (3) is analyzed to identify actions and operations that are likely to require assistance. Using the model, the designer can consider cognitive and physical aspects that lead to failures. The system designer must also figure out how the assistance system could recognize a situation to proactively support the user. A wide range of input and output devices is available for HEI (human-environment interaction) today, spanning a large design space. The choice for modalities determines how the interaction with the system will look and feel and is crucial for the usability and acceptance of the system. Once sensors and actuators have been chosen, the problem of where to physically place them arises. Particularly optical devices, such as cameras and displays, have a limited field of view that needs to be considered. The VR model allows the designer to precisely plan and assess the instrumentation in 3D. Finally, the chosen HEI technology is attributed to the analogous actions and operations in the situated activity model.

(5) System Implementation The contextual knowledge about activities can be applied for the implementation of activity recognition components. The geometric model can be reused for indoor positioning and location-awareness, and the ontology can be applied to uniquely denote parts of the domain and to share knowledge between applications.

2 Use Case: Modeling Interaction in the SmartKitchen

The SmartKitchen is an instrumented kitchen environment that has been instrumented with sensors and a large display to realize the *SemanticCookbook* [4] application that provides proactive user assistance on how to prepare a meal. The system uses multiple sensors: i) wide-angle video cameras that record the cooking session, ii) RFID equipment that identifies ingredients and artifacts that are in use, and iii) networked kitchen appliances. Figure 1 depicts how we have modeled the environment graphically and symbolically with the YAMAMOTO toolkit, as described in [5].

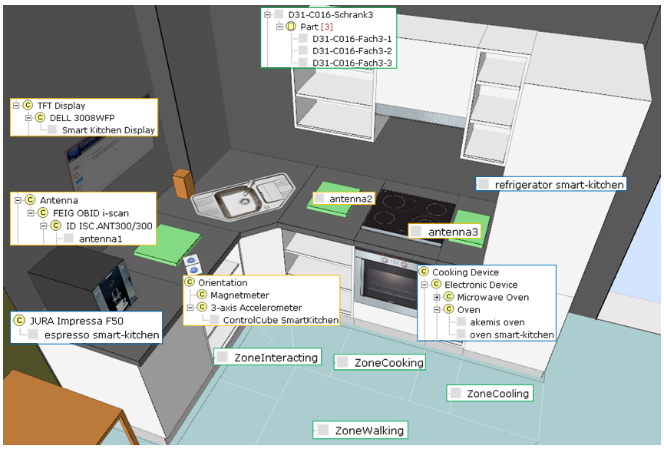

Fig. 1. Geometric model of the SmartKitchen and symbolic names for its parts.

Activity/Action/Operation	Subject	Artifact	Purpose	Location
Prepare Bruschetta				
Activate Oven	user	oven		ZoneCooking
switch on	user	oven	Activate oven	ZoneCooking
choose heat type	user	oven	Set proper heat type to toast bread	ZoneCooking
set temperature	user	oven	Set temperature to 180 C	ZoneCooking

Table 1. Exemplary cooking activity in the kitchen.

We will now describe an exemplary action from the non-assisted bruschetta activity (see Table 1). The first action is named "Activate Oven" and subsumes the operations that are necessary to set up the oven's heat type and temperature in order to toast the bread. They refer to the oven as artifact and to the cooking zone in front of it. In Table 2 we have modeled the interaction between the user and the assistance system and added HEI instrumentation. The *SemanticCookbook* has been designed to instruct the user how to prepare a dish step-by-step by presenting multimedia content of pre-recorded video and speech. At the beginning of each step, the system gives a verbose summary of what comes next and the display lists the required artifacts and ingredients. The user now has to put the listed items on the kitchen's worktop where they will be sensed through the RFID reader. If all items are complete, the system proactively continues the

Activity/Action/Operation	Subject	Artifact	HEI
Prepare Bruschetta (assisted)			
breakpoint1	SemanticCookbook		
Gong	SemanticCookbook		Display
Text and speech	SemanticCookbook		Display
Highlight items	SemanticCookbook		Display
Confirmation1	user		
Manual confirmation	user		Control Cube
(or) place cutting board, bread knife and bread on RFID area	user	Bread-knife, cutting board, bread	Antenna1
Present selection 1	SemanticCookbook		
Play video section 1	SemanticCookbook		Display
Present selection 1	user		
Cut bread in slices	user	Knife, board, bread	

Table 2. Assisted preparation of bruschetta with the SemanticCookbook.

playback of the instructions. Alternatively, the user can manually confirm that the necessary items are at hand through a control cube.

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