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Conceptual Modeling for Ambient Assistance

Judith Michael, Heinrich C. Mayr

Application Engineering Research Group, Alpen-Adria-Universität Klagenfurt, Austria
{judith.michael, heinrich.mayr}@aau.at

Abstract. This paper addresses the conceptual modeling of a person's daily activities, i.e. units of purposeful individual behavior. An integrated set of such models is intended to be used as a knowledge base for supporting that person by an intelligent system when he/she requires so. The work is part of the HBMS[1] project, a research project in the field of Ambient Assisted Living: HBMS aims at supporting people with declining memory by action know-how they previously had in order to prolong their ability to live autonomously at home.

***Keywords*:** Conceptual Behavior Modeling, Ambient Assistance, Behavioral Support, Cognitive Impairments, Activity Theory, User Context.

1 Motivation

With the ongoing acceleration of professional and private life, memories tend to become more transient. Whoever has not already experienced it to overlook a detail or to temporarily forget how to do something: *"What was the sequence of buttons to be pressed for starting a DVD film", "What was I supposed to keep in mind when completing my tax return electronically"*. Immediate assistance is rarely available in situations such as these, or it might be impracticable, too expensive or too imprecise (for example manuals, FAQ lists). This affects particularly elder persons, who experience a growing forgetfulness, and thus increasingly need assistance. Coupled with demographic change, the demand for support services grows exponentially.

An obvious solution lies in support by pervasive computing in as far as this is justifiable and feasible from a psychological, ethical, legal, and technological perspective.

As humans are mobile, support services must be mobile too, adapted to the respective environment and the particular situation. This leads us to the term *Ambient Assistance* [1], describing unobtrusive and, if desired, ubiquitous support. *Ambient Assisted Living* [2] aims particularly at enabling the elderly or persons with impairment to live independent and autonomous lives. Numerous projects deal with the support of healthcare processes through the use of terminal devices, e.g. MARPLE [3], Care-Mate [4]. Other approaches aim at supporting the cognitive performance of an indi-

[1] Human Behavior Monitoring and Support: funded by Klaus Tschira Stiftung GmbH, Heidelberg

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vidual in everyday life situations [5]. As an example, Zhou et al. [6] use Case Based Reasoning methods for that purpose; Giroux et al. [7] employ plan recognition.

The HBMS - Human Behavior Monitoring and Support Project [8] relies on conceptual behavior modeling. It aims at deriving support services from integrated models of abilities and episodic knowledge an individual had or has temporarily forgotten.

This paper focusses on the modeling aspect of HBMS, concentrating on the description of units of individual target-oriented behavior and their relevant context. It is organized as follows: Section 2 sketches the HBMS aims and architecture, followed by a discussion of various approaches to human behavior modeling (section 3). In section 4 we address the aspects of user context in accordance with [9]. Section 5 introduces the conceptual modeling language HCM-L. The paper ends with a brief report on the experiences gained with a first HBMS prototype, and with an outlook on the next steps for research (section 6).

It is important to us to point out that the HBMS main goal was not to invent just another modeling language. However, from our studies we had to learn that the existing languages do not exactly fit to the needs of modeling human behavior for later support. There are two main reasons: (1) as natural languages continuously are changing along societal development, also modeling languages should be flexibly adaptable for abstracting particular issues. (2) Standardized all-round languages have their merits but often do not provide means for expressing matters to the point efficiently. For instance, following the evaluation of Wohed et al., there are no sufficient solutions in UML Activity Diagrams [10] and BPMN [11] for modeling synchronizing merge patterns, i.e. situations in which a decision relates to a situation earlier in a process.

As a consequence, we endorsed the view of the Open Modeling Initiative OMI [12]: namely to allow for domain specific languages that are tailored for a given application purpose though based on common fundamentals. Such languages then may be lean (few and powerful concepts) and more intuitively used by users from the respective application domain (in our case: psychologists, care givers etc.).

2 HBMS: an overview

With HBMS we target individuals at any age, who desire a form of support that builds on their own (earlier) practical knowledge. In several workshops and through a survey designed especially for this project, participants requested support in a variety of areas, such as, e.g., the operation of multifunctional devices, participation in eGovernment processes and the use of reminders to help with appointments, taking medication or shopping lists [13]. Fig. 1 shows the development stages in the HBMS Project:

Stage 1: Everyday activities of an individual are observed in a test environment and are textually recorded. From these descriptions conceptual models are derived and integrated into what we call a *Human Cognitive Model (HCM)*.

Stage 2: Observation of behavior patterns is automated by use of sensors or monitor tracking; the data gathered is semi-automatically transformed into a model, which again is integrated into the HCM. During this stage, assistance still has to be requested by the target person, and should adapt itself to the particular situation and context.

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Stage 3: Behavior and context (e.g., state of devices, environmental parameters) is observed automatically if wanted, and support is offered automatically (by comparing currently observed behavior from HCM content), where needed. This final phase, however, does not lie within the current scope of the project.

HBMS is an interdisciplinary project, as it not only looks at the informatics-related issues of elicitation, modeling, management, extraction, and representation, but also aims to explore and clarify psychological, technical, legal, and ethical considerations.

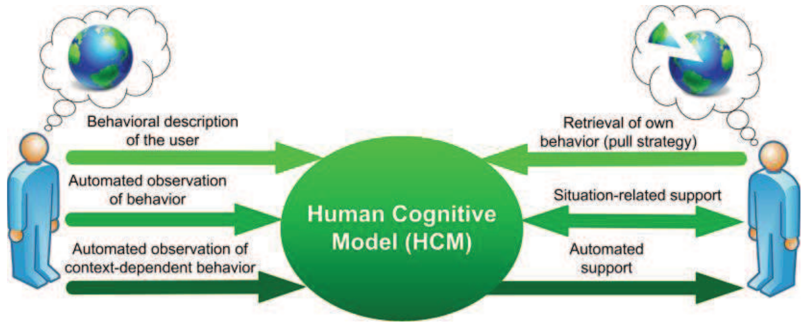

Fig. 1. The development stages in the HBMS Project

Other publications emerging from the HBMS project look closely at the overall project concept and the target groups [8], explore the project architecture and the results of an empirical study carried out with potential users [13], describe the integration of behavioral models [14], discuss quality management aspects [15], and report on a comprehensive control pattern-based analysis of our modeling language [16].

3 Approaches to modeling human behavior

The modeling of human behavior and actions has been studied in several disciplines for understanding and predicting human behavior (including, a military perspective, e.g. [17]). Behavioral modeling has also been addressed in the context of so-called "synthetic agents", e.g. [18]. Researchers in the field of Psychology use behavioral models in their exploration of processes of judgment and decision-making.

Activity Theory forms an essential foundation [19]. It involves observing the nature of human activities on three levels: The level of the *activity* (the overall process), the level of the *action* (subtasks) and the level of *operations* that realize actions. While activities are informed by *need*, individual actions each pursue a specific *goal*. As the actions meet with success, the need of the overall activity is extinguished. In order to put these actions into effect, individual operations are performed.

Activity Theory rests on five principles: the *hierarchical structure of activities*, *object orientation*, *mediation*, *continuous development*, and *differentiation between internal and external activities*. The suitability of this theory for Human Computer Interaction (HCI) was successfully demonstrated in [20]. In further studies, the theory is also used to model the contexts of specific situations [21].

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The modeling concepts applied can vary enormously depending on the respective goal. For example, [7] lists so-called "lattice-based models", supplemented with probabilities, Bayesian networks, Petri networks, rule-based approaches, and ad-hoc modeling. [22] uses Semi-Markov models to identify Activities of Daily Living (ADLs).

The focus of HBMS is on supporting individuals with their own concrete, episodic knowledge (memory of experiences and specific events). For this purpose, the modeling concepts referred to above are only of limited use, as they can be used to describe actions and their sequences, but do not capture the situational context in detail: for example, the remote control of a DVD recorder, and its precise layout.

Conceptual modeling languages such as the Unified Modeling Language UML provide these possibilities, as long as they cover the modeling dimensions [23]: Structure view (e.g. UML class diagram), functional view (e.g. UML methods), and dynamic view (e.g. UML activity diagrams or state charts). Conceptual business process modeling languages focus on series of actions and generally do not include own concepts for the modeling of structure views; instead they refer to those of the UML. The Business Process Modeling Notation BPMN serves as an example [24]. Despite their expressive power, these languages have weaknesses as has been sketched in section 1.

Our goal is a lean and simple language focused on modeling human behavior that adopts proven concepts from existing languages and waives unneeded ones. The concepts were developed by building upon the experiences gained with KCPM [25], a user-centered language for requirements modeling.

4 User Contexts

Human behavior is determined by more than merely the activities themselves. It is important to consider the context, within which the respective person is moving. In [9] the user context is divided into separate areas: the *task context*, the *personal context*, the *environmental context*, the *social context*, and the *spatio-temporal context*.

The main focus of HBMS is on the *task context*: Everyday activities of a person have to be modeled in detail and in all observed variants, their motives and goals; e.g. to reach the goal of watching a particular DVD film: take the DVD and TV remote control, press the resp. ON buttons, select the desired function buttons etc.

The *personal context* of an individual refers to information about mental and physical parameters including handicaps. This information will be valuable during the 'productive' phase, i.e. when providing support to a person with declining cognitive capacity: to choose the best medium and form for help presentation, or to trigger an alert to a relative or medical professional in case of observed degradation. Clearly, this has to comply with all associated ethical and data protection issues.

The *environmental context* refers to the environment of a user, for example: persons and things, with which one communicates or interacts like the remote control.

The *social context* comprises the social environment of the target person: information about friendships, relatives or colleagues. For the purpose of HBMS, such persons will be 'modeled' if they are linked to certain activities. Should future users' needs require broader types of social relations, our approach will be adapted.

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The *spatio-temporal context* draws upon information about time, frequency, duration of activities, locations, and movements.

Fig. 2 depicts the role of context in HBMS. A *Behavioral Unit Model (BUM)* represents an integrated view on all *observed action sequences* of a particular activity. BUM's are grouped in topical *clusters*. BUM's, clusters and the sequence models of observed actions together form the task context.

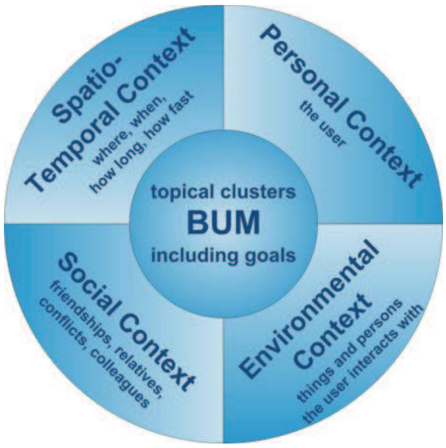

Fig. 2. Context models in HBMS

5 The Modeling Language HCM-L

The aim of HBMS is to support a person on the basis of a model of his/her own behavior. Thus, the HBMS modeling language focuses on concepts for modeling the (sequences of) actions of a person and their contexts in detail. Such sequences are not necessarily identical, even when sharing the same objective: they can vary, e.g., in their order or due to the omission of certain action steps. Consequently, the modeling language must offer concepts for abstracting action variations such that subsequently all possible variations can be derived (as instances). This is analogous to so-called *case prototypes* in case-based reasoning [26] functioning as abstractions of all related cases, and corresponds to "*product lines*" in software engineering [27].

The next sections describe the key concepts of our *Human Cognitive Modeling Language HCM-L* and their most important (meta) attributes; following [28], the HCM-L syntax is described by a meta model (fig. 3), the semantics by explanation and the notation by a set of graphical elements.

5.1 Behavioral Units and activities

The key concept of HCM-L is that of *behavioral unit.* It is defined as an aggregate of *operations* which together lead to reaching a *goal* in daily life (see *Basic* [5] or

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Instrumental [29] *Activities of Daily Living*). Thus, a behavioral unit corresponds to an action as defined by Activity Theory, and to a "use-case" in business process modeling, e.g., fulfilling the goal to watch a particular DVD film. Typically the operations of such action form a sequence; this is captured by the concept *flow*: *outgoing* from the predecessor operation and *incoming* for the successor. Since a behavioral unit's goal may be reached by different sequences, the unit may have one or more *possible beginning* (meta attribute) and, similarly one or more *successful ending*. The *goal distance* indicates the length of the shortest path to a successful ending.

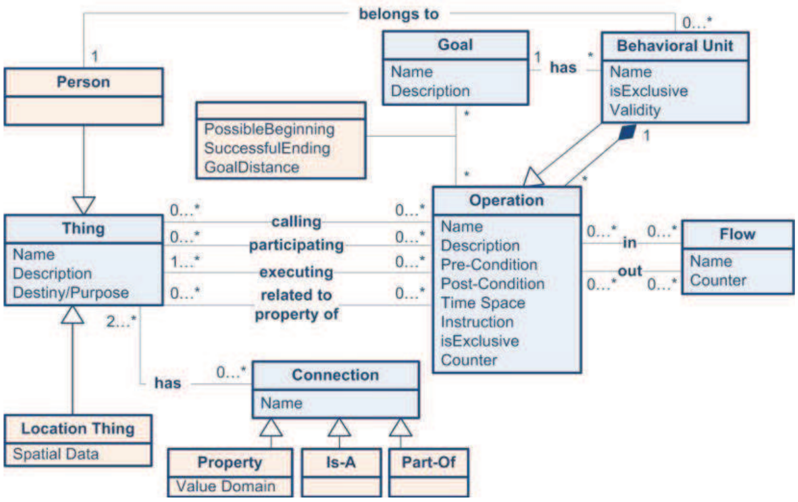

Fig. 3. Meta schema of the HCM-L definition with key attributes

The granularity chosen will depend on the prevailing circumstances. For example, one could perceive the tying of shoe laces as a behavioral unit, but this could also be viewed as an operation of a broader unit of "putting shoes on", which again could be seen as an operation pertaining to a unit "getting dressed". In other words, behavioral units themselves can be regarded as operations. This is supported in HCM-L by the generalization relationship between behavioral unit and operation.

To be executable, an operation may depend on a (possibly complex) *pre-condition*. For example, the DVD player must be switched on, before a DVD can be loaded. Similarly, the execution of an operation may set a *post-condition* that, e.g., has consequences on the subsequent flow. These conditions refer to properties, time and space circumstances. In particular they occur with process branching and merges.

It might surprise that we do not model conditions separate from the operations like e.g. in Petri nets or event process chains. This emphasizes our focus on operations, the sequences of which become transparent in lean diagrams (see Fig. 5). Clearly, these could easily be expanded into bipartite graphs separating conditions and operations.

Instruction defines the functional semantics of an operation. For situations where an operation or even a whole behavioral unit should or cannot be interrupted by another one, HCM-L provides the meta attribute *isExclusive*.

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Operations can (or must not) occur at specific points in or periods of time, and they may have a duration. This is captured by the attribute *Time Space*. The formal language for specifying conditions, time spaces and value domains is work in progress and reflects the research presented in [30]. It is clear, however, that, regardless of the selected language, the limits of intuitive comprehension are soon reached (see above), as most individuals have only learned to handle simple logical linkages. Realistic modeling and, automated model creation nevertheless require such a language.

5.2 Things and Connections – Elements in the world and their relationships

For modeling the context of actions, HCM-L adopts the concepts *thing* and *connection* from KCPM [25]. Things describe arbitrary concrete or abstract objects, also persons, connections model relationships between things.

Every subject and object has a *destiny* (in the sense of the purposes it serves). This meta attribute will be important for support: using a thing against its intension (e.g., a comb to brush the teeth) may induce starting help.

The person to be supported has to be modeled her/himself (concept *person*). Thus, the modeled behavior can be associated to this person (association *belongs-to*).

The concept of *Location Thing* was introduced to allow capturing spatial data as precise as necessary (e.g. coordinates, temperature, humidity, noise etc.): e.g., it is important to know where the remote control was deposited after last used. The meta attributes of the location thing concept are based on [6], where these attributes are compiled from sensor data and recorded as vectors in a case-base.

Operations are related to things: there are *calling* things, which initiate operations, *participating* things, which contribute to or are manipulated by operations, and *executing* things, which perform operations.

The connection concept has specializations to (1) *property* relations such as “the remote control has a display (thing)”, that can show the current channel (*value domain*); (2) Aggregation and decomposition (*part-of*), and (3) specialization and generalization (*is-a*). A thing is called *attribute*, if it is target of a property.

5.3 Graphical representation

The graphical representations of the few HCM-L concepts are shown in Fig. 4. They follow the principles for designing effective visual notations presented in [31]. In line with these, behavioral units and their context can be modeled and reproduced in a combined form.

Figure 5 shows a simplified version of the operations and flows of the behavioral unit ‘evening activity’. The model has been developed and drawn using the HCM Modeling tool which was developed using the ADOxx® platform [32], and equipped with a simulation interface for visualizing concrete operation flows. Since the picture should be self-explanatory, we only hint at two specifics of HCM-L:

‘watch a DVD’, ‘watch TV’ and ‘read a book on the e-reader’ are aggregations (operations with sub-operations). When clicking on the ‘+’ symbol the resp. submodel is shown;

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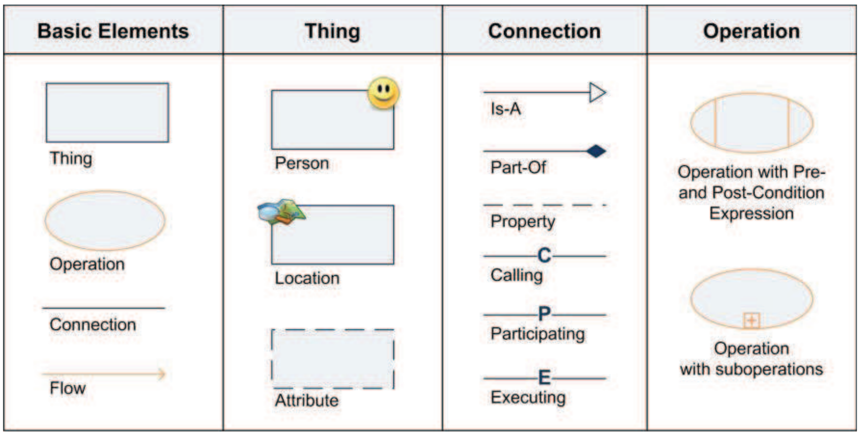

Fig. 4. HCM-L modeling symbols

Post-conditions may be headed by the logical operations AND, OR and XOR leading to flow forks with the resp. semantics. Pre-conditions may be headed by AND (regular merge), XOR (simple merge) and SOR ('synchronized or'). The latter always relates to a Multi-Choice construct occurring earlier in the actual instance of the behavioral unit and denotes a wait until all incoming branches have been performed. For more details see [16].

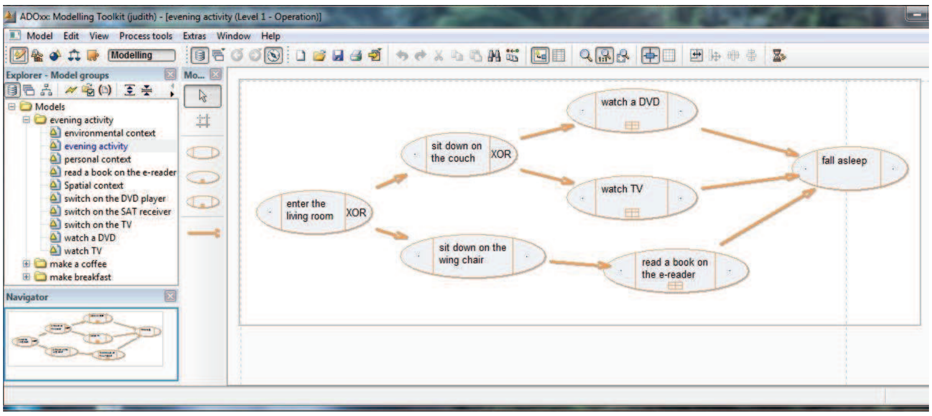

Fig. 5. Operations and flows of a behavioral unit 'evening activity'

Unfortunately, there is not space in this paper to show also a picture of the complete context model or further screen-shots of the model details. The interested reader is referred to the HBMS website http://hbms-ainf.aau.at/.

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6 First experiences and future perspectives

To check the completeness of HCM-L for the intended use, a pattern-based analysis [16] has been performed on the basis of the Workflow Pattern framework (www.workflowpatterns.com).

Another check was the compliance with Activity Theory [19]. Unfortunately, there is not enough space to report on the (positive) results in detail.

For a proof-of-concept we developed a HCM Modeling and Support Tool. It provides a graphical interface for modeling [33] and the possibility to present derived support information on a handheld device [13]. This prototype was firstly tested on 40 individuals (mostly ages 50+) on the occasion of the "Long Night of Research, Austria" event, using as an example the preparation of a cup of coffee. The respective operations of each individual were modeled, and then rendered as a set of step-by-step instructions on a smartphone or a tablet PC. The visitors regarded this kind of support system, both for themselves and for their environment, as meaningful and useful in everyday life; we received a consistently positive feedback. Some people wanted to take the prototype home immediately, and putting it to use.

Currently, we run an evaluation with 60 people in 3 age groups to assess the support mechanisms concerning the textual, graphical and multimedia representation. The experiences made, and the comments and suggestions gathered on these occasions have resulted in adaptions/extensions of the meta model leading to the version presented within this paper.

The next step will be a real life experiment with a particular test person.

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