Using cognitive models for behavioral assistance of humans

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Self-Portrayals of GI Junior Fellows

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Abstract: Cognitive impairments are a rising challenge in society. Everybody has experienced events of forgetting what one was going to do when entering a certain room, or where one has put the keys, the purse or the smartphone. Such problems mostly occur under stress or fatigue. And they may increase with age up to diseases like senile dementia or Alzheimer which affect mental tasks like memory or reasoning, and thus often lead to the need of comprehensive assistance. Due to the societal change, the number of people suffering from such impairments is continuously growing. Cognitive modeling may provide human-centered solutions for this challenge since a cognitive model of a person's behavior, regarding activities of daily living, can serve as a knowledge base for support actions. This paper presents a Domain Specific Modeling Language for Ambient Assistance: The Human Cognitive Modeling Language (HCM-L). It was developed to preserve the episodic memory of a person in the form of conceptual behavior models including relevant context. The work is part of the Human Behavior Monitoring and Support (HBMS) project, a research project in the field of Ambient Assisted Living funded by the Klaus Tschira Stiftung gGmbH. HBMS aims at monitoring a person's behavior using activity recognition techniques, generating models from their output, and providing focused and timely support by the use of intelligent reasoning mechanisms.

Keywords: Domain specific modeling languages, ambient assistance, cognitive model.

ACM CCS: Human-centered computing → Ubiquitous and mobile computing → Ubiquitous and mobile computing theory, concepts and paradigms → Ambient intelligence, Software and its engineering → Software notations and tools → Context specific languages → Domain specific languages

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1 Introduction

Cognitive impairments are a rising problem in society. Independent from our age problems like forgetting what one was going to do after entering a certain room, where one has put the key, the purse or a smartphone can happen everyone who is stressed or overtired. This cognitive loss may also increase dependent on the age: The number of people suffering from a disease like Alzheimer or from other dementia symptoms, which affect mental tasks like memory or reasoning, is growing worldwide [17].

Current research concentrating on the technical support for this cognitive decline is mainly connected to the *Ambient Assisted Living (AAL)* domain. AAL is a research domain initiated by the European Union [16]. It is concentrating on the technical support of elderly people to empower them to stay as long as possible in their domestic environment. Support of cognitive functions is one research topic amongst others like mobility support, fall detection, inclusion in the working process, leisure or healthcare.

The HBMS project, a research project in the field of AAL, aims at deriving support services from integrated models of abilities and episodic knowledge that an individual had or has, but has temporarily forgotten. The main core, the *Human Cognitive Model (HCM)*, preserves the episodic memory of a person in the form of conceptual models of behavior linked to context information related to this activities.

The investigation, which modeling concepts and which characteristics of a modeling language were needed to enable the modeling and reproduction of empirical knowledge, was the main research question of my dissertation. Thus, the *Human Cognitive Modeling Language (HCM-L)* [10] was developed for this purpose.

This paper gives an overview of the HCM-L, shows an example, discusses the idea of having an intuitively understandable modeling language for the target persons and presents the HBMS context model.

2 Cognitive modeling for ambient assistance

The terms *'cognitive modeling'* or *'models of cognition'* originate from cognition psychology and are important concepts for cognition science as well as for Artificial Intelligence (AI) [3]. In psychology and AI theories of how humans solve a certain problem are tested by using a computer program, which tries to have the same control processes during problem solving as humans have, e. g., Newell and Simon with the General Problem Solver [13]. The main goal of cognitive modeling is to find out the basic principles of human intelligence by checking if a given AI-model is able to find solutions for a problem similar to human problem-solving processes or the opposite way, where psychological findings about the memory are validated by simulation using AI-techniques [15].

This work adds a new variant to the concept of cognitive modeling, which is closer to the meaning of modeling in Informatics: *The cognitive model, as an extract of the episodic knowledge of a person, is used as knowledge base for connected services such as support activities.* Models are encapsulated units of a certain persons' behavior. These HCM-L models form a knowledge base for reasoning services to optimally support a person: they are the core of the HBMS-System, and the central source of knowledge for other system components. The idea of using conceptual modeling methods, which are commonly known from software engineering, for building this cognitive model, is new in the AAL domain.

2.1 HCM-L

A preceding analysis of common (generic) modeling languages revealed that these did only partly fulfil our requirements [8]. As a conclusion we decided to create a Domain Specific Modeling Language (DSML) fulfilling the main *needs*: the modeling language should (A) provide models which can be used as a knowledge base in the support system, (B) focus on human behavior and its context, and (C) is intuitively to understand by the relevant stakeholders of the AAL domain, e. g. people in general and their relatives, care givers or doctors. The *purpose* for creating the DSML was to model human behavior restricted to daily activities in the private home of one person. [11]

A semantic analysis of HCM-L [8] showed that it is – for the domain of Ambient Assistance – sufficiently powerful and fits the need of modeling human daily activities of one person better than general purpose languages like BPMN or UML.

HCM-L is a lean modeling language which serves to represent and reproduce episodic knowledge of a certain person without loss. The scope is limited to the episodic knowledge of a person (autobiographical events and contextual information) and is further restricted to activities, which should be supported in the future HBMS system.

Following [5], the HCM-L *syntax* is described by a meta-model, the *semantics* by explanation and the *notation* by a set of graphical elements. The modeling language is grounded in activity theory [7], which describes the nature of human activities in general.

The language is describing units of goal-driven human behavior and its context. The key modeling concept 'Behavioral Unit (BU)' encapsulates sequences of actions ('Operations') that lead to a BU's goal. There are concepts for context modeling, which cover the personal context (e. g., mental and physical restrictions of a person), the environmental context (e. g. furniture or resources), the social context (e. g. relatives, care-givers), and the spatio-temporal context (e. g. location, time, frequency or duration of activities).

To use a DSML in practice requires to embed it into a Domain Specific Modeling Method (DSMM), which includes the procedure of how to apply the language as well as appropriate mechanisms and algorithms to be used in such procedure. In [11] we proposed a guideline for how to create such a DSMM. As a modeling language without tool support is useless in practice, a modeling tool based on the meta-modeling platform ADOxx® was developed [9].

Section 2.2 introduces the HCM-L by using an example model from the HCM-L Modeler. For an in-depth description of the modeling language and the detailed meta-model, the reader is referred to [10].

2.2 Example

To gain a better understanding of how HCM-L can be used, the following example of Maria should help.

Maria is working on a full-time basis in an office. Now she is in her sixties and she has recognized, that she forgets more and more things: her key for the office, the handbag and at least once a week she is searching for her purse. She is unable to remember if she has locked her door at home or has switched off the coffee machine. She always wants to be appropriately dressed when she is going to work in the office. But recently it happened that she wears casual shoes together with elegant dresses, casual clothes on days with important appointments and she forgets to

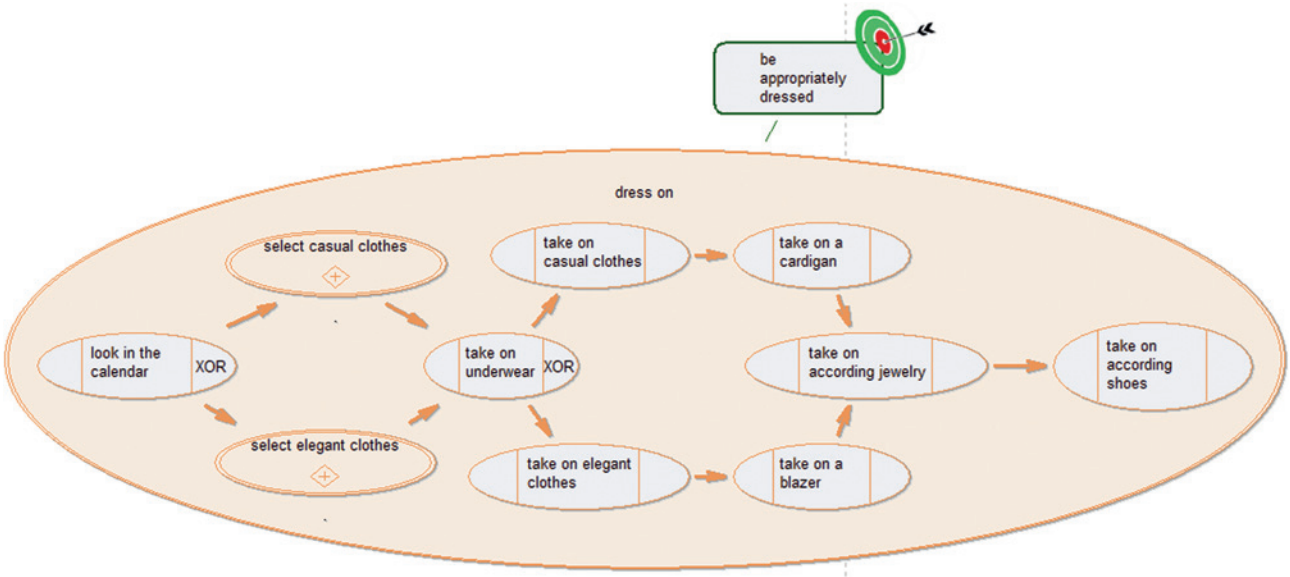

Figure 1: The BU 'dress on' modeled with the HCM-L Modeler in the Behavior Unit Model view.

take on a blazer and jewelry as usual. If she would have installed an HBMS system some time before, her common daily activities, e. g., dressing on, having breakfast, being prepared for shopping, taking her medicine or getting prepared for leaving the house, would have been preserved and could be taken as a basis for support.

Figure 1 shows one of these models for the activity 'dress on', a BU with several operations leading to the goal of being appropriately dressed. Maria starts every morning with looking into her calendar to decide, what she should wear this day. As the reader might easily deduce from Figure 1, there are branches and merges in the execution flow of the behavior. The first 'XOR' is a decision of Maria based on the information in her calendar. She selects either casual or elegant clothes and prepares them on her bed. Depending on the color of the upper part of the selected clothes, she takes on according underwear.

For more demanding pre- and post-conditions, a textual language is available but hidden from the basic graphical representation; this is to reduce the semantic complexity of the models. The second 'XOR' is such a post-condition: depending on the execution of selecting casual or elegant clothes in the process path before, the Operation 'take on casual clothes' or 'take on elegant clothes' is selected. After taking on a cardigan (for the casual look) or a blazer (for the elegant look), Maria selects according jewelry and takes on according shoes for the outfit.

Operations are performed within a personal, environmental, social, and spatio-temporal context. Thus, each operation is *connected to relevant concepts* of the activities *structural context*, e. g., the Operation 'look in the calendar' is connected to the calendar itself, a certain location where it is and the person interacting with it. These concepts are presented in other model views described in Section 2.4.

To help humans dealing with the complexity of models, modeling of hierarchies is an important feature. The Operations to select casual or elegant clothes have a diamond at the bottom of the symbol. It indicates that the resp. Operation is seen and modeled as a BU again. Paper [1] shows a 'morning activity' as an example, where the 'dress on' BU (Figure 1) could be a part of it.

2.3 Intuitive understandability of a modeling language

To model is a common human activity: We have models to show where the electrical lines in a house are, we sketch processes or relations between elements on a piece of paper for an easier discussion with others or use a pie chart of a table to be cognitively more effective.

One of the key needs for our DSML is the intuitive understandability of the models by our future users. Therefore we had to create graphical concepts which are *intuitively understandable* for the *relevant user groups*: the supported persons, relatives or care givers. We used research results about designing cognitively effective visual notations [12] to create a graphical notation that fits these needs.

The HCM-L models were evaluated in several qualitative studies regarding the goal of intuitive understand-

ability. The concrete results of the first study can be found in [1], a paper for all studies' results is under preparation. The majority of the participants understood that the presented graphic (a similar BU model to that in Figure 1) shows activities and actions within a certain sequence and that a hierarchy exists. As it was expected, the conditions seem to be challenging for a larger group of participants. A simulation of the possible ways through the behavioral process might be a possible solution to improve understandability.

Another way of improving understandability are different views on the model to support cognitive integration and complexity management.

2.4 Context modeling

As the term *context* is used in several research fields, context models exist in several domains, e. g., in pervasive environments [2], for Business Processes [14] or for Geographic Information Systems [4]. The structure of our context model is a domain specific variation of a user-centered context definition used in [6].

Figure 2 shows the different context models in relation to each other. Starting from the bottom, we get *Sequences* of behavior from activity recognition. These are integrated into already existing models or enriched with structural context information and added as new behavior to the knowledge base.

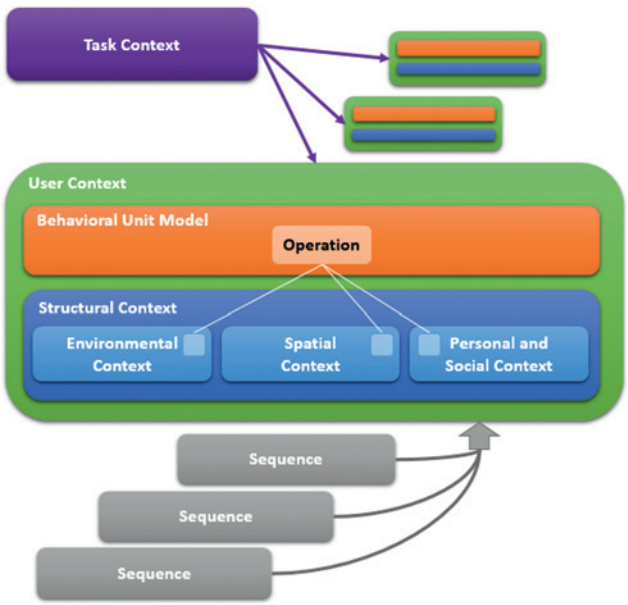

Figure 2: Overview of the Context Models.

The *User Context* represents the combined behavioral and structural information about a certain BU. The *Behavioral Unit Model* (see also Figure 1) is a behavioral view on the activity with its' BUs and Operations. Each Operation is connected to elements in the *Structural Context*, which is divided into the *Environmental Context* (e. g., furniture or resources), *Personal and Social Context* (e. g., the person itself, mental and physical restrictions, preferences, relatives, and care-givers) as well as the *Spatial Context* (e. g., locations or connections between rooms).

To provide mechanisms for cognitive integration, all BUs in the system are presented in the *Task Context* (see also [10]).

3 Discussion & outlook

Cognitive modeling is a highly demanding and challenging topic, especially in the domain of Ambient Assistance. This paper presented what my research is focusing on. There are several colleagues in the HBMS project working on related research topics, e. g., activity recognition, formal language specifications, model integration, reasoning, multimodal interaction, ontology linking or psycholinguistics. The fruitful discussions about topics at the boarder of these research fields makes it possible to get new ideas for further research.

Currently, I'm working on concepts for representing spatial information (rooms, the situation of elements in the rooms) in a better way, to link context information to common ontologies and a structured adaption of the use of a cognitive model for supporting humans to other domains.

As a GI junior fellow it is important for me, that research in Informatics brings a benefit to the society in general – as we try to do in our projects.

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