Cognitive Modeling and Support for Ambient Assistance

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Abstract. The aim of the Human Behavior Monitoring and Support (HBMS)[1] project is to learn about the individual skills and behavioral knowledge of a person in order to support that person when needed. It is intended as a contribution to enable elderly people to live autonomously in their domestic environment as long as possible. The basic idea is to build a cognitive model of the behavior of a person while she/he is of sound mind and memory. In case of mental incapacitation this model will be used as a knowledge base for generating support information. The paper outlines the first results of the HBMS project with a focus on the investigative survey and the overall architecture of the chosen approach.

Keywords: Cognitive Modeling, Ambient Assistance, Model Integration.

1 Introduction

We are facing unprecedented demographic changes in recent years. The European population aged 60 and above is rising by more than 2 million per year [1]. Life expectancy is increasing sharply, and so is the number of people who will need care—which will lead to exploding healthcare costs [2]. The working population is decreasing, and so we have to find solutions to the problem of how care for the elderly will be handled without enough human resources available.

Ambient Assisted Living (AAL) is a research area that seeks to develop methods to support elderly people in their everyday life. Steg's definition is instructive [3]:

> *"AAL aims to prolongate the time people can live in a decent way in their own home by increasing their autonomy and self-confidence, the discharge of monotonously everyday activities, to monitor and care for the elderly or ill person, to enhance the security and to save resources." (p. 28)*

The main aim of AAL is to enable the elderly to live longer and as autonomously as possible in their domestic environment, thus decreasing healthcare costs and helping them to reach higher satisfaction with their quality of life.

Previous research has concentrated on usability and security aspects of technical devices, but so far, little attention has been paid to cognitive support. Our project,

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Human Behavior Monitoring and Support (HBMS) [4], whose goals we present in Section 2, aims at filling this gap. In Section 3 we discuss a psychological survey case study that we used to explore the needs of the elderly. The main question was to determine aspects of everyday life where people might require support and areas where they do *not* want help. We present preliminary results based on a specific questionnaire and interviews with a number of elderly people. In Section 4 we present a prototype system as a proof-of-concept. We conclude by outlining how our findings could be used in the future and defining HBMS as a contribution to support elderly people who want to live longer and more autonomously in their own environment.

2 HBMS: Human Behavior Monitoring and Support

The main idea of the Human Behavior Monitoring and Support (HBMS) project is to support people in their everyday life [5] when cognitive functions like, e.g., memory are decreasing. This might happen when we are getting older and the brain is suffering from neurobiological changes. Such decrease can also happen independent of age, for example if we are stressed or unpracticed in doing specific activities.

HBMS wants to support people by retrieving forgotten knowledge. Therefore it is necessary to build a cognitive model of a person's behavior while she/he is of sound mind and memory. In case of mental incapacitation this model will be used as a knowledge base for generating support information. HBMS will not compare the behavior of different people as some studies do (see [6]) and it will not suggest how someone should act in a particular situation compared to others. The main objective is to retain information about how a person performed actions herself or himself before, not how a third person performs an action (which in most cases could be different).

2.1 Aim and Target Groups

The aim of the HBMS project is to learn about individual skills and a person's behavioral knowledge in order to support that person later when needed.

Individual behavior related to observed scenarios is mapped to sequences of actions. If sequences of the behavior are missing in the daily routine, it will be possible to support the person with his/her own knowledge and in his/her own words.

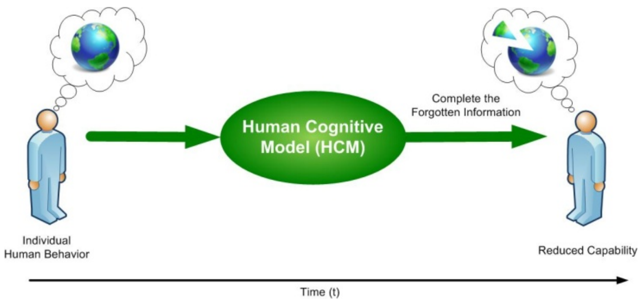

Fig. 1. Support by a person's own (former) knowledge

Fig. 1 shows that the Human Cognitive Model (HCM) tries to complete missing steps of activity or other information for a person. The missing information, e.g., which button is the next one to descale the coffee machine, or how to program the video recorder, could be offered if necessary.

The target group for the project is in fact everybody who could benefit in the future from being reminded of their former, forgotten knowledge, independent of the person's age. As already indicated above, we often forget things if we are stressed, overtired, or untrained when we perform actions outside of our ordinary routine. Consequently there is practically no restriction to possible user groups for HBMS. In detail the target groups have different requirements regarding their age, their circumstances in life, or individual needs. Therefore we decided to choose a more general approach. The individualization is reached by using HBMS and learning the behavior and ontology of each individual person.

We focus on scenarios from four different areas of everyday life: the use of technical devices, activities of daily life, business processes, and ambient environments.

2.2 The Process

Fig. 2 illustrates the HBMS process for an individual person. It is possible to preserve the individual memory of a person by building a cognitive model of her/his behavior.

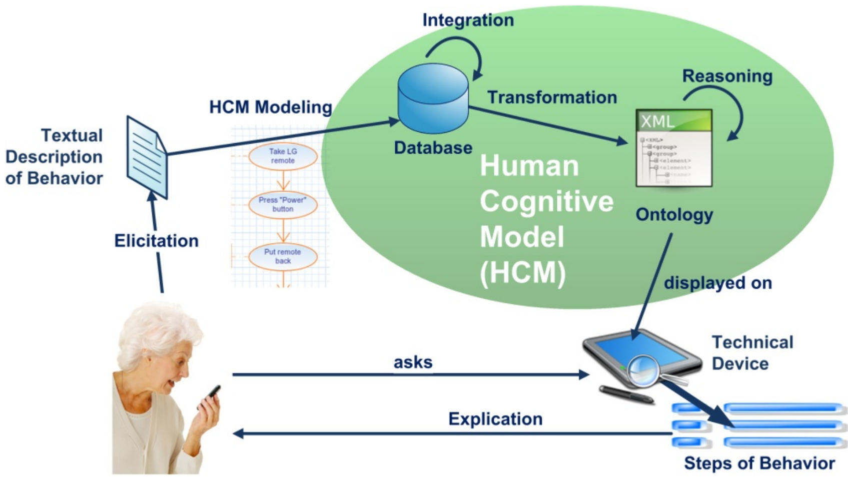

Fig. 2. The HBMS process

Observation will be done automatically in a later project phase, e.g., activity and intention recognition [7], the usage of smart meters to detect and individualize Activities of Daily Living [8] or the usage of sensors and Case Based Reasoning (CBR) for activity recognition [9]. At the first stage a psychology domain expert observes a person and writes down the different steps of action, e.g., as they use a coffee machine. Behavioral sequences of the person's Universe of Discourse are elicited step-by-step, mapped to and integrated into a cognitive model (HCM, Human Cognitive Model). The meta-model of the HCM is created based on concepts of the Klagenfurt Conceptual Predesign Model (KCPM) [11], which are adapted to the structure of human behavior and human intention [12]. In the long term we plan to refine it with techniques from CBR [13]. For model integration we will reuse and adapt methods from [10] to the new requirements of HBMS.

This model then is transformed to a formal ontology which allows inferring, by reasoning, new knowledge as the given situation may demand. If an individual needs support for an action, HBMS can return information about missing steps out of his/her former knowledge, e.g., on a technical device like a smartphone, tablet PC, or perhaps in the future some other kind of "smart environment."

3 Empirical Study

A central question that needs to be addressed in the context of AAL is what people with reduced cognitive capability need to cope in their everyday lives. We gained this information by including future users. We used a number of methods, including a questionnaire, a workshop with students of all ages and analysis of results from other scientific studies of this topic. We gathered preliminary data from December 2011 to March 2012. We sent the questionnaire to all students of the Alpen-Adria-Universität Klagenfurt. During the study period, 203 persons of all ages participated. Fig. 3 shows the detailed age distribution.

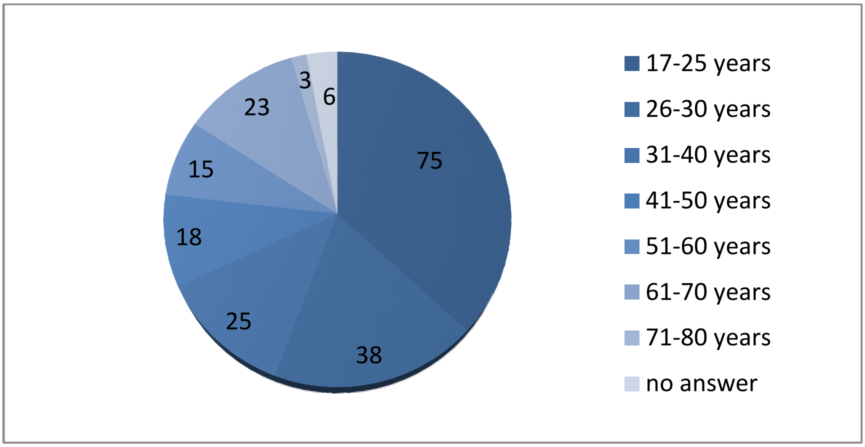

Fig. 3. Age distribution of the survey participants [values in absolute count]

Predictably, the age class under thirty years is overrepresented (55%) which correlates to the development of the student structure. The results of all ages are interesting to find out if there are differences between age classes and their attitudes toward technology.

Our results so far seem to suggest that there is interest in a system that offers cognitive support on multifunctional devices, especially for businesses like online government, and reminders on contents of conversations, dates, or the shopping list. Another conclusion at this point is that activities that people do not repeat regularly are most vulnerable to being forgotten.

3.1 The Survey

We performed an investigative survey to find out which kinds of support might be useful for users and how it should be provided.

One result from the questionnaire is that people believe the use of e-banking and e-government processes is becoming increasingly important. However, these processes are often difficult to handle and hard for customers and citizens to remember. At the same time, the number of office workers available to help will decrease.

Not only are technical devices getting increasingly complex, our everyday life does as well. Schedules, dates with other persons, deadlines for submitting applications, taking medicine at a specific time, and reminders for the shopping list are matters people would like to be reminded of when dealing with them. These results correlate with those received in Berlin through a voluminous and highly qualified study [14]: memory, knowledge and perception speed are skills that are often progressively diminishing and could adversely affect the ability to cope with everyday life. While our conclusions remain tentative, as another result the data reveal a basically positive attitude to technology for all age classes in our study.

Nevertheless, these results must be viewed with a critical eye: the students were invited and not forced to participate the survey, and it is likely that those students who are not interested in technical processes at all did not take part. However, what we can say is that there is no difference between age and attitude to technology for those people who participated.

To show some possible scenarios for HBMS systems, we defined two scenarios indicating how the system could be used in the future. Maria, a fictional 75-year old person has problems using her video recorder. The question given to the participants was if they could imagine that an acoustic signal, e.g., a voice, is guiding Maria through the right order in which to press the buttons. As shown in Fig. 4, 87.25% of the participants were able to imagine that scenario and would like to have this possibility for themselves too.

Comments given to this scenario were that it would be useful because of the easy and fast support, but there was also a desire to switch the system off if it is not needed and to change the data output, e.g., not a voice but support on the screen of the television.

At the same time, 6.37% of the participants do have problems with this scenario and could not imagine being supported by an automated system in this case. The most common criticism was that family contact could be reduced as a consequence of the decreased need for help.

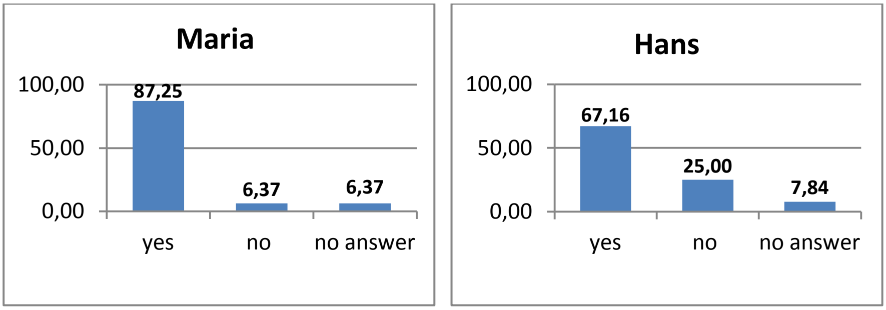

Fig. 4. Example of Maria and Hans

The second scenario was about Hans, a fictional 50-year old man whose local bank branch was closed and so he had to do his banking business via Internet. If he had problems with it, he could be supported by a voice, e.g., telling him about the next steps necessary to finish the transactions. 67.16% of the participants could imagine this scenario for themselves too, as seen in Fig. 4.

Most people who refused this scenario criticized possible security problems w.r.t. these sensitive data. Interestingly enough, two thirds of participants did not worry about this problem.

Performing online financial transactions is becoming increasingly important. 63% of the participating students are already using e-banking for their everyday needs. In any case, almost every fourth participant answered that he/she is reliant on help when using online banking.

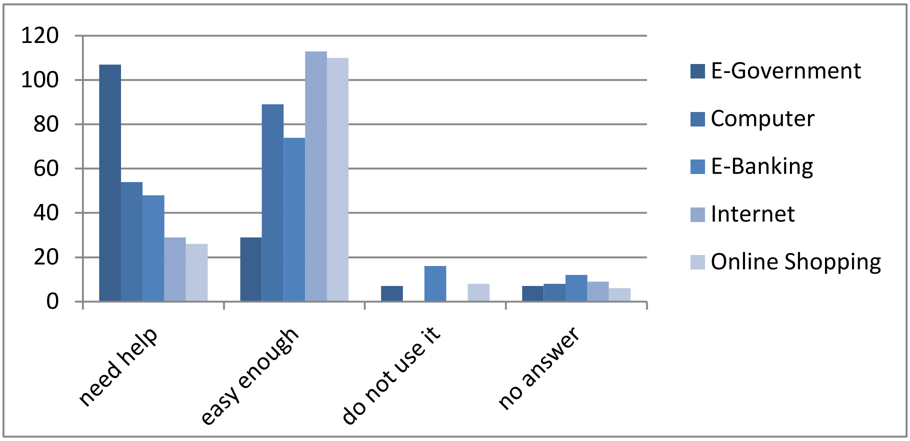

Fig. 5. Possible areas of support

Fig. 5 shows for which areas the participants find help necessary and which are easy enough to use: using the Internet, doing online shopping or using the computer seems quite easy. The use of e-government services turned out to be most difficult (registration inquiries, registration of dogs, communal tax declaration).

Using domestic technical equipment seems to be easier. Fig. 6 shows that study participants believed turning on the television or the washing machine to be simple. Every fourth participant indicated the need for help using a mobile phone, and we confirmed this in the interview phase of our study as well. The most frequent answers were that (1) smartphones have too much functionality so that it is difficult to execute the desired function, and (2) that infrequent actions (like changing the password or ringtone) are forgotten quickly.

A similar example given by a 62-year old workshop participant was her experience with using her digital camera. Using it at the standard settings is no problem, but changing the white balance is not simple for her.

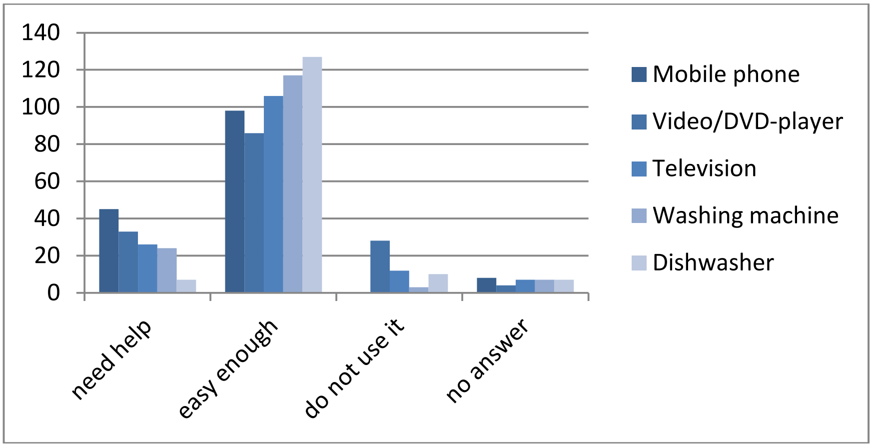

Fig. 6. Areas of support for domestic technical devices

3.2 Conclusion

As we have seen, there is considerable interest in a support system as intended by our project, HBMS. However, potential users expect that it should be easy to switch off such a system when they do not need or want it. Ways in which we should present output data of such a system to users is not yet completely clear: we will learn more about that when testing and using the prototype.

At the current stage of the project we have focused on support for using a coffee machine, monitoring the usage of a washing machine, and providing appropriate assistance for e-government services as early test scenarios. In a next step we will add further scenarios mentioned in the questionnaire and we will incorporate ideas that came from workshop participants.

Based on the response to the survey we decided to add information to the Human Cognitive Meta-Model (HCMM). Users want data like pictures or videos included in behavioral steps. Voice output, as proposed in the scenarios for Maria and Hans, is vital. Users should also be able to choose between acoustic, visual, or other support in order to meet individual preferences and needs. Moreover, participants strongly demand the ability to customize such a system. We need to provide this, which means including customization elements in the data schema.

4 The Prototype System

The questionnaire and workshop gave us deeper insight into the people's needs. But a questionnaire alone is not enough to evaluate our ideas. Even though implementation is not the focus of our research, we developed a prototype system as a proof-of-concept. With the prototype it is possible to show potential future users how this system might help them. The HMBS system contains the modeler tool, integration and transformation applications, and explication services in different domains.

4.1 The Architecture

The HBMS system is based on a client-server architecture (see Fig.7). At the client side we distinguish the modeling, network, and mobile domains. On the server side are the integration, ontology, and service domains.

The standalone HCM Modeling Tool implementation is based on the Eclipse Rich Client Platform (RCP) [15]. A set of very useful editing features, such as automatic layout and aligning, drag-and-drop, and direct editing support are provided by the Eclipse-based graphical framework Graphiti. The representation concepts of the Human Cognitive Modeling Language (HCML) are fully supported by the modeler. The Hibernate framework is used as persistence layer for retrieving and storing the HCM model in a relational database. The integration of additional observed behavioral sequences to the generalized HBMS model using Case-Based Reasoning (CBR) and Natural Language Processing (NLP) is performed automatically.

In the ontology domain, data is retrieved from the relational database through Hibernate and then transformed into the Web Ontology Language (OWL) [16]. The transformation is done by server-side processing using transformation techniques like QVT (Query/View/Transformation) or ATL (ATLAS Transformation Language) [17]. The resulting OWL files generated by the JENA Framework [18] are stored in the file system on the server. The ontology editor Protégé is used for prototype development and visualization of these ontologies.

In the service domain, the data to support the individual user are processed. As in adaptive demotic systems the OSGi framework is used to allow uniform access to services [19]. The implemented OSGi bundles are organized in a layered architecture. The base tier is the persistence layer where the OWL files are stored in the Knowledge Base Bundle.

The middle tier represents the processing logic where the result of the query is converted into a generic step-based data structure. The service tier is the presentation layer which provides public services that can be accessed by appropriate devices. The mobile domain includes all mobile devices, e.g., smartphone, tablet PC, and notebook with wireless network. The network domain characterizes all devices (workstations, terminals) in the local network.

To ensure comfortable and versatile use, mobile devices are currently used as the output medium. Communication with server components runs via web interfaces to allow an appropriate presentation on the end-user devices.

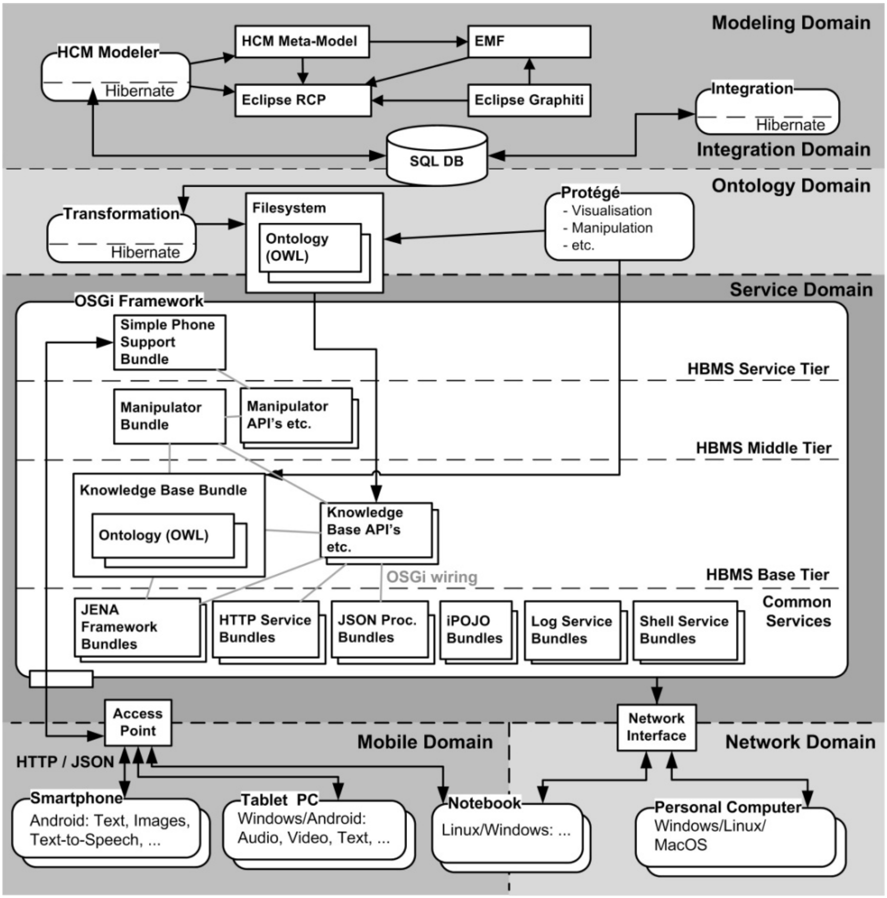

Fig. 7. Architecture of the HBMS Prototype

4.2 Tools and Applications

Related to the four scenarios mentioned in Section 2.1, we map a person's individual behavior steps to sequences. This model contains static and behavioral aspects. To do this, we use our know-how in conceptual modeling (KCPM, Klagenfurt Conceptual Predesign Model [11]) and evolve the KCPM concepts to cognitive modeling. The Human Cognitive Modeling Language (HCML) is still under development. More information can be found in [20].

Fig. 8 shows a screenshot of the HCM Modeling Tool prototype. In this application it is possible to model behavioral sequences as well as static components and to make them persistent in the database.

As with [10] and [21], we integrate the sequences in a background process to a generalized model. Starting from this point, the integrated, generalized, and enriched model is a Human Cognitive Model (HCM). The transformation from HCM, an ontology language for behavioral and episode description, into a suitable representation language is also a background process. Due to increasing popularity of the Semantic Web, we chose OWL as the ontology representation language.

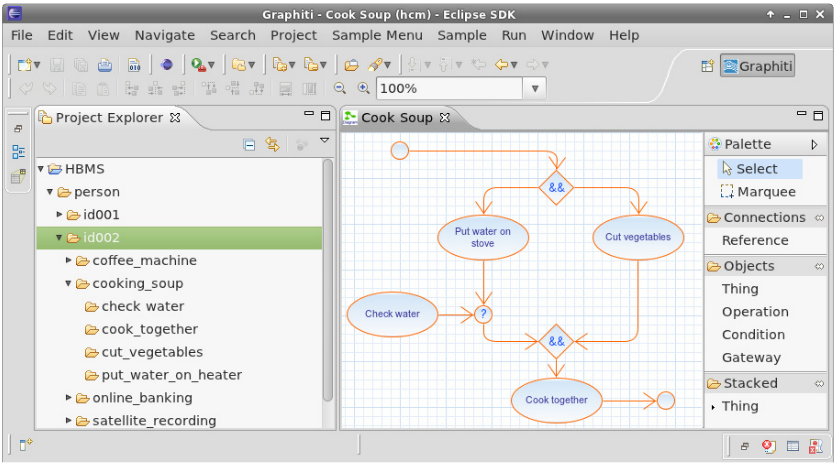

Fig. 8. Screenshot of the HCM Modeling Tool

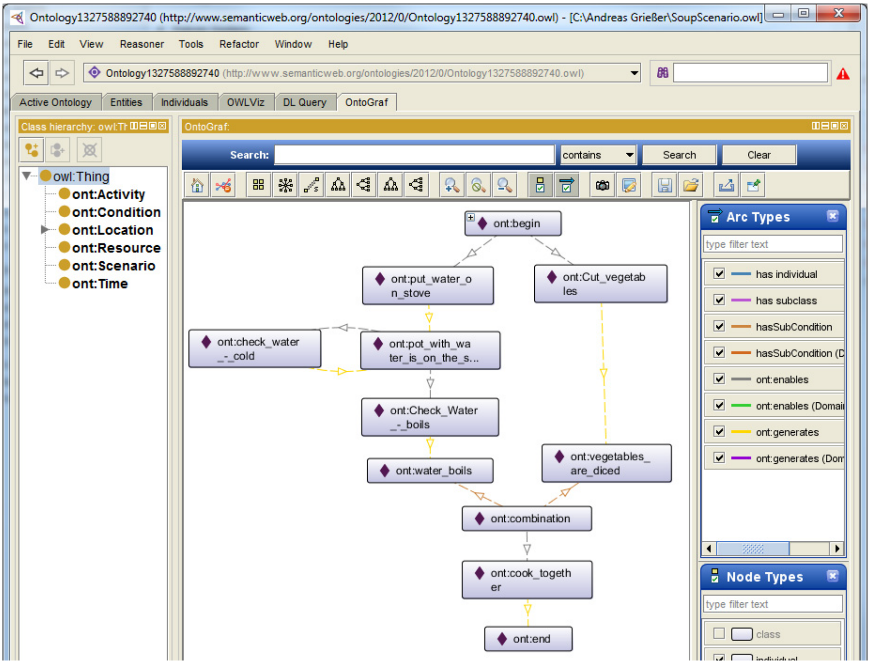

Fig. 9. Soup-cooking ontology visualized in Protégé

Ontologies as explicit formal specifications of conceptualizations include integrity and inference rules that need to be derived. OWL is desirable for this purpose as it has the ability to express semantics, constraints, and individuals of the problem domain. The transformation of UML activity diagrams to OWL has been examined in [22] and can be successfully applied to our project in a similar way. For lossless and consistent transformation of HCM, we will also develop behavioral model mapping rules.

Fig. 9 shows the ontology that results from transforming the HCM model given in Fig. 8. Reasoning allows us to derive logical conclusions and new knowledge from known behavioral steps. Several implementations of so-called reasoners are freely available in third-party libraries [23].

5 Summary and Outlook

Challenges for our society lead to interesting and exciting topics for research like Ambient Assisted Living. To sum up, with HBMS we propose a solution for everybody's need for independence from third parties while performing certain activities. We are working on methods for creating a cognitive model and using it as a basis for situational support. Our prototype enables us to elicit and model behavioral steps and to integrate them into a Human Cognitive Model which then is transformed to a formal ontology. As a last step, information requested about missing steps can be returned for an individual person, e.g., on a mobile device, tablet PC or in a smart environment. Our prototype will be presented to several groups of end users. Their feedback will be used for further development within the project.

Ongoing and further work includes the exploitation of methods from Natural Language Processing for modeling [21] and Case-Based Reasoning [9]. There are many alternatives for rendering generated support information, e.g., via mobile devices, especially w.r.t. emerging opportunities for speech analysis and synthesis, but also via specific in-room multi-media systems. Multimodal interaction will be provided to make the use of HBMS accessible and intuitive.

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