Instrument-Oriented Approach to Detecting and Representing Human Activity for Supporting Executive Functions and Learning*

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ABSTRACT

The goal of this study is to develop a computer-interpretable model for activity detection and representation, based on existing informal models of how humans perform activity. Appropriate detection of purposeful human activity is an essential functionality of active assistive technology aiming at providing tailored support to individuals for improving activity performance and completion. The main contribution is the design of a model for detection and representation of human activities based on three categories of instruments, which is implemented as two generic and supplementary terminology models: an *event* ontology and a *core* ontology. The core ontology is extended for each new knowledge domain into a *domain* ontology. The model builds the base for personalization of services generated by the cooperative reasoning performed by a human collaborating with an intelligent and social software agent. Ongoing and future work includes user studies in the different application domains.

KEYWORDS

Activity recognition, Human-agent interaction, Knowledge representation, Ontology, User modelling, Activity theory, Assistive technology, Decision-support systems

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1 INTRODUCTION

An intelligent environment is typically dedicated to optimise human performance in different ways, for instance, compensating for decrease of ability, e.g. as a cognitive tool to remember tasks or guide in accomplishing activity [2, 13, 23]. Systems embedded in the environment can show the autonomous and proactive behaviour, which typically is assigned computational programs denoted *intelligent and social agents*. If the software agents are dedicated to optimise human performance and well-being, they also need to detect, represent and evaluate activities performed by the human. Human activities however, are sometimes overlapping in time, and conducted in different order, utilising different sets of sub-actions, which adds complexity to be handled. Moreover, a large part of human activity is managed through complex cognitive functions such as planning, reasoning, decision making, and developing knowledge and skills. In addition, human motivation and emotional influence on activity is significant.

Typically, methods for detecting human activities in daily living and working include statistical methods such as machine learning, where feature extraction and activity classification based on large amount of data is done (e.g. [5, 21]). We aim to address the activity recognition problem by using a semantic approach, based on theories of human purposeful activity. Activity and intention recognition approaches presented in research are typically aiming at lower level observable actions, such as walking, sleeping, or heading for a particular direction. We adopt an activity-centred perspective instead of a user-centered perspective, where the user is included as one part of the activity system. This enables us to i) characterise the conduction of an activity, ii) relating this to the characteristics of the actor (capacities and limitations), and iii) to the contextual constraints on activity (domain knowledge, environment, etc.). We expect that this will facilitate the personalisation of the support that an active assistive technology can provide [13].

The aim of the work presented in this paper is to develop a generic computer-interpretable model related to activity recognition and support generation based on informal and formal models for describing and explaining human activity (e.g., [12]).

The main contribution is a common model for representing the events generated when a human actor conducts activity, which captures the minimal information needed for advanced analyses of activity progression, performance and fulfilment of the human agent's goals and motives. This common model of activity can be used as base also for the software agent's agency, in order to define its purpose and goals.

The paper is organised as follows. A description of the methods applied is provided in the following section. The characteristics of activity is described in Section 3, followed by how representing activity as events (Section 4). In Section 5 we describe how activity can be detected based on the instruments a person uses. Implementation of the results is presented in Section 6, and current relevant research is described in Section 7. The article ends with conclusions and directions for future work.

2 METHODS

For creating a model of human activity and agency, theories and models of *human activity* developed within different research domains were studied. We primarily used the Activity Theory for categorizing and interpreting activities to represent knowledge about recognizable purposeful activities [12], and the International Classification of Functions, Disability and Health (ICF)[1] formed a baseline model for human activities and abilities.

We focus on three different knowledge domains related to health, which are relevant to a human actor who is an older adult. The *knowledge domains* are i) the diagnosis and management of neurocognitive disorders including dementia, ii) an intervention targeting older adults, related to the physiotherapeutic domain, and iii) older adults living in their home environment with some difficulties, representing the occupational therapy and nursing domains.

The model was implemented as two ontologies using Web Ontology Language (OWL)[2] which is an extension of the Resource Description Framework (RDF)[3]. RDF is a graph-based data model with labeled nodes and directed, labeled edges, which makes it a flexible and dynamic model for representing data. The nodes and edges can be augmented with additional information, and the edges represent the relationship between two resources. The Web Ontology Language (OWL) is an international standard for encoding and exchanging ontologies (i.e., terminology models) and is designed to support the Semantic Web. Consequently, the structures can be used for reasoning. RDF and OWL are the underlying representation formats for the models developed as a part of this paper. The model is integrated in applications for dementia care, falls prevention and an ambient assisted living environment.

3 CHARACTERISTICS OF ACTIVITY CONDUCTION

Following Activity theory, an activity is defined by its objective and consists of a set of goal-oriented actions. An *activity system* includes the actor or actors, who are using instruments and the instruments are viewed as *mediators* for activity [12]. The role of objects can be either *instruments*, i.e., mediators, or the focus of activity, i.e., the *objective of activity.* The role of an object often shifts, by the actor's shifts of focus. We will in this section outline a model, which implements these activity-theoretical concepts and their relationships. Detecting *focus shifts* and the *role of objects* are considered a means for detecting objectives and goals for activity, and consequently, providing support tailored to the human actor's reasoning process and style of thinking. It should be noted that an object can be either a physical item or mental, abstract artefact. It should also be noted that in our model we include both human and software agents as actors.

Assistive agents need to detect human activities of different kind in order to provide appropriate and situated support. The kind of support to be provided can be adapted to the different ways in which an activity is conducted. An assistive computer application can be more or less structured and proactive, depending on the needs and preferences of the human actor. For example, the dementia diagnostic support may function as a template, or a checklist in the data capture and diagnostic process following a forward chaining process (i.e., diagnostic reasoning). The support may also be provided following a more causal reasoning process, where the human actor can propose a hypothesis, and have an argumentative dialogue with the application agent about the strength of

[1] http://www.who.int/classifications/icf/en/
[2] http://www.w3.org/OWL/
[3] http://www.w3.org/RDF/

the hypothesis (e.g. [27]). These two ways represent the same activity, since they share the same motive and will have the same outcome: an optimally assessed diagnosis.

Table 1: Activities categorised by the type of instruments mediating the activity

Activity constraint	Required skills	Instruments	Example
Activity requiring domain knowledge	Factual and process knowledge in a particular domain	Structured knowledge-based protocols	Activities based on evidence-based clinical diagnostic criteria
Activity requiring social knowledge	Social knowledge	Language, dialogue and behavioral norms	Human-agent dialogue activities
Activity depending on a physical(-virtual) environment	Handling physical environment	Physical instruments available in the environment	Physical activites (body and space) or Instrumental Activities of Daily Living (iADL) such as maintaining food and medication intake routines

However, these two ways to conduct the same activity are different, and become represented differently in the *event repository* defined and implemented in our work. While the main activity in both cases is dementia investigation, the sub-actions and their organisation will differ, which will follow the individual physician's line of thinking. Moreover, both contain reasoning and decision making, but only one is *social*, in the sense that negotiation between two potentially conflicting standpoints is included.

Our third example case is when an activity is carried out in a physical, or physical-virtual environment where the physical and virtual items play the role as instruments. In this situation, skills and knowledge about how using the physical and virtual tools and environment are needed. This kind of knowledge is different from the knowledge and skills in a particular medical knowledge domain required in the dementia example, and the social and behavioural knowledge and skills required in the dialogue example.

In the following sections, we categorise types of activity following these three categories of knowledge and skills required to conduct the activity (Table 1). This way we can assess the capacity of the human in performing the activity, based on how they handle the instruments. Moreover, by representing activity and utilise a purposeful model of the activity in the provision of support to the human, higher-level goals and motives can be inferred by their actions and interactions with the supporting agent.

4 REPRESENTING THE HUMAN ACTOR'S ACTIVITY AS OBSERVED EVENTS

The basic concept commonly used in generic ontologies is *event*, for representing an observable happening in the world[20].

We chose to build the *Actor repository* based on an event class, where each instance of an event has properties that relate the event instance to information about the event (Figure 1).

In our implementation an event has a *start time* and an *end time* (Figure 1). End time means "end of focus time" following activity theory, meaning that the activity could either be ended, paused, cancelled or be ongoing in parallel, then requiring minimal attention.

Moreover, an event is always associated to an *activity*. The identifier of the activity is drawn from the *Domain knowledge repository* for the particular application. The activity associated to an event corresponds to one of the three types of activity introduced in the previous section: 1) domain knowledge-based (protocol-based) (Figure 2), 2) social knowledge-based (dialogue-based) (Figure 3), or 3) physical environment/instrument-based, observed in a physical environment (Figure 1).

Each event may also have associated *observations* and *evidence* (Figure 1). The difference between these two types of information is that evidence is information, which has been preceded by some reasoning, either by a human or software agent. As such, it can be challenged, and defeated in an argumentative reasoning task, e.g. in a dialogue. Moreover, evidence can be treated as the outcome of an activity, e.g. as a decision about a diagnosis in the dementia example.

An observation can also be challenged by conflicting observations that may contradict the first observation.

The events represented in the Actor repository are typically nested, which represents the Activity-theoretical hierarchical model of activity where human activity contains several layers of actions.

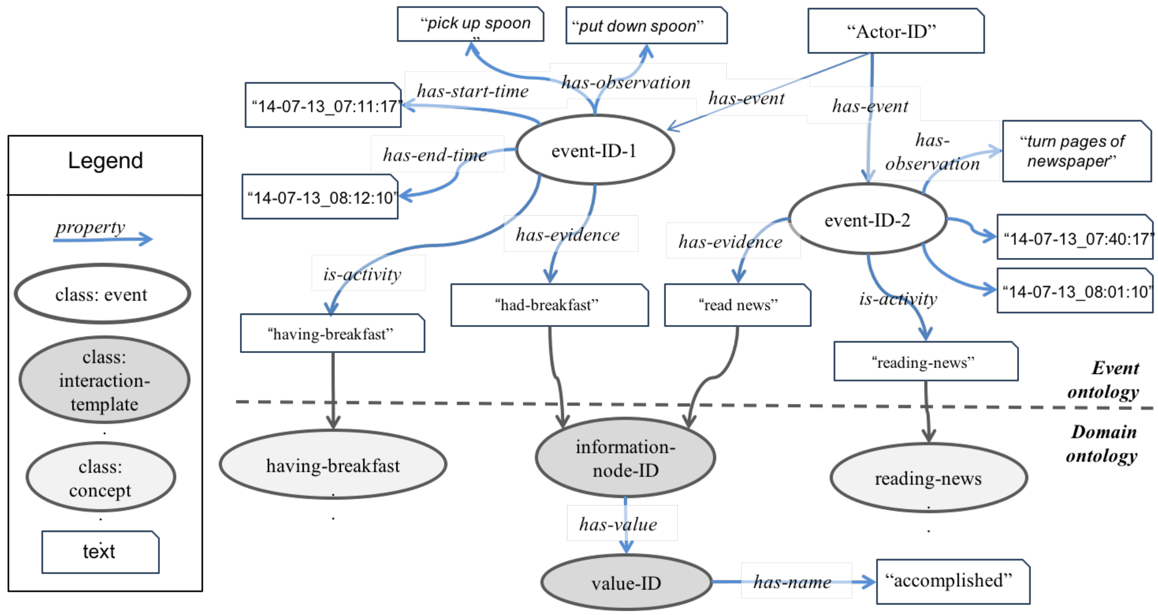

Figure 1: Example from a physical home environment where an older adult is having breakfast while reading the news. The identifier of the event is a concept that represents an activity.

5 DETECTING ACTIVITY THROUGH THE INSTRUMENTS USED

In this section the three contextual constraints on an activity that relate to instruments are further explored and exemplified. We begin with the physical, or physical-virtual environment.

Activity Constrained Primarily by a Physical Environment

A fundamental view of Activity Theory is that human activity is mediated through *instruments*, or tools [12], which is embedded in the concept iADL (*instrumental* activities of daily living). Consequently, the primary key to identifying activity is to detect the instruments involved in the activity. A human actor uses both her body and other objects as instruments. One example is that based on 3D sensor information, the human movement of an arm and hand with an object in the hand can be interpreted as an activity involving the object as the instrument, while a movement without an object may be interpreted as a gesture with some communicative purpose, where the arm and hand become instruments.

Therefore, next the *role of the involved object* needs to be determined. There are two options: the object may be the focus of activity, or merely a mediator of activity. If the object is the focus of activity, this reveals the objective of the activity. One example is when a person is cooking porridge, there are objects involved such as the pan, spoon to stir the content, milk, water, oat meal and salt. The focus of activity is what is becoming food in the pan, which can be detected by the amount of visual focus is given to the cooking pan, and not the salt, oat meal, milk or water.

The collected data obtained by the agent in an environment are interpreted into *observations* at a low level. These are typically collected using various sensors, such as accelerometers, 3D sensors etc. and can be operations such as gestures, holding objects, moving, sitting still, clicking on a particular button in an application, etc. Such observations are associated to an event by the property *has-observation* (Figures 1, 2). When these observations are obtained in a physical environment, the agent analyses the situation, and associates the set of observations to a preferred activity pointed out by the human actor during a baseline assessment, and which is represented in the domain ontology, e.g., "having breakfast" or "taking medication".

Domain knowledge-based activity

The domain ontology for each knowledge domain and related application has a class for *interaction templates*, which represent the instruments which the domain professionals use in their design of a support application, when using the knowledge-management system ACKTUS. One

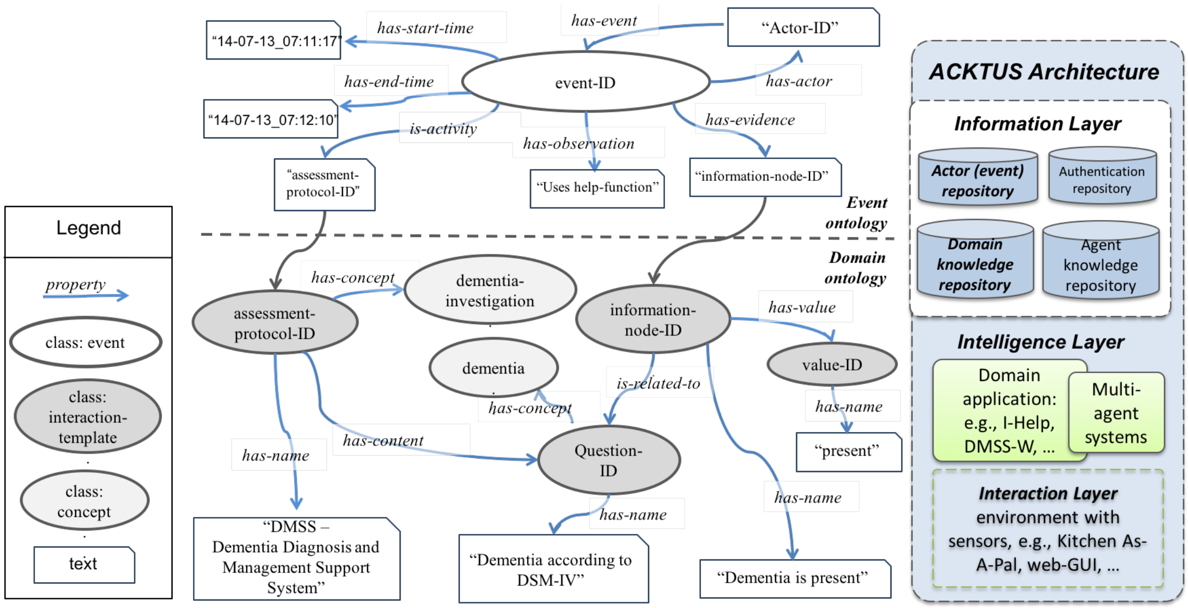

Figure 2: Example from the dementia domain of *protocol-based activity* and an overview of the ACKTUS architecture that implements the model.

sub-class is *assessment-protocol*, which represents templates for conducting activity [17].

A *protocol-guided activity* is identified by the assessment protocol's associated activity concept, and the assessment protocol itself functions as an instrument in the performance of the activity. For instance, the assessment protocol building up the dementia support application has the name *Dementia Diagnosis and Management Support System*, and has the concept *dementia investigation* (Figure 2). Consequently, the name of the tool in combination with the concept, pointing to which activity the tool is aimed for, follows the activity-theoretical model of purposeful activity, which is necessarily mediated through instruments.

Social knowledge-based activity

Activity that requires social knowledge is for example, dialogues between an older adult and a nurse on health-related topics, or a physician having a dialogue about diagnosis with an expert agent (Figure 3). In the case when an intelligent and social software agent acts as a knowledgeable dialogue partner, it also needs to behave in a way, sensible to the human and follow the human's line of reasoning across topics. In our approach, we define such *human-agent dialogue* by the *generic goal*. This generic goal is related to the type of dialogue that is chosen, where the type refers to the purpose and expected outcome of the dialogue. One example is *inquiry dialogues*, which aim at creating new knowledge in collaboration between the actors taking part in the dialogue [26]. During the dialogue however, the human and agent interact over one or more sub-dialogues on a *specific topic*. For example, when the older adult meets a nurse, the nurse has certain information about the person through the patient health record system (EHR). In our human-agent dialogue activity, the agent fetches this information about the human from the Actor(event) repository. The agent accesses the previous event-ID, and gathers information about the last dialogue if any with the person based on the Actor-ID. If the person has initiated the dialogue, then the generic goal is based on the specific topic, such as "memory" which means the generic goal is to figure out if memory-related problem is being faced by the person.

Continuing with the example, the nurse asks memory-related questions to the human, if the human is finding "difficulty in doing everyday activities", takes any "medication" etc. Once the nurse has information about the human's health condition, she can make a conclusion about the presence/absence of memory problem and together they come up with solutions of "what can be done to reduce the memory related problem" being faced if any. In the human-agent dialogue activity, the agent provides advice to the human on what can be done for the betterment of the condition. Sometimes it can mean

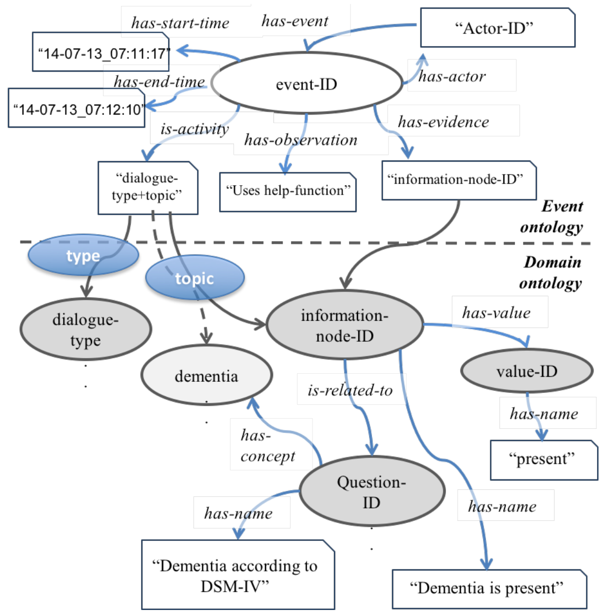

Figure 3: Example from the dementia domain of *dialogue-based activity* where depending on dialogue type it can have as topic a concept, e.g., *dementia*, or an information-node that is a statement e.g., *Dementia is present.*

to "change priority of some activity" by the human, such as taking medication to be of highest priority than previously being only important. Another example is when the agent fetches previous event-ID and observes that the human has not called her son, then the agent can try to persuade her to call and talk with her son. The software agent follows certain dialogue and behavioral norms based on the preferences and priorities selected by the human to decide when, where and how to present the information. For example, the agent performs an activity on behalf of the human which the human has decided to do, such as, "send reminders about an appointment with the nurse". It is to be noted here that all the text in quotation marks forms a sub-goal for the agent during a dialogue. The human and agent switch between different types of dialogues within a generic goal with topic: memory. Thus, a human-agent dialogue starting with a particular topic, can be nested to meet sub-goals in the process of achieving the overall motive for the dialogue activity. In this way, the activity-theoretical notion of hierarchy of activity can be represented in a dynamic and situated way, following the human's cognitive processes.

6 IMPLEMENTATIONS OF THE MODEL AND VALIDATION OF KNOWLEDGE

The model consisting of the core ontology and the event ontology has been implemented and integrated in different kinds of support applications through the ACKTUS architecture (Figure 3). The applications and their knowledge bases have been developed and evaluated by healthcare experts and researchers in the different expert domains (e.g., [15, 16]). The software agent's model of the human's goals and motives is built upon knowledge content modelled by domain experts. Depending on the human's current priorities and situation, this goal model is adapted accordingly by the agent [14]. The more generic hierarchical structure of human activity is embedded in the core ontology (e.g. *managing food intake* is a super goal of *having breakfast*).

The domain knowledge-based (protocol-based) activities can be easily implemented and deployed among users, which is the case of the Dementia Diagnosis and Management Support System (DMSS-W) [18], the Safe Step application for falls prevention in older adults [15], the COPD-management web site [4] and a self-treatment application for incontinence [5].

In the Dementia Diagnosis and Management Support System (DMSS-W) the event ontology is currently used for collecting data that may be used for detecting levels of knowledge and skills in physicians and based on this provide person tailored support [18]. An experiment on integrating an agent-based dialogue system into DMSS-W is also presented [27]. I-Help (HemmaVis) is a mashup application for supporting older adults in daily activities [3, 10]. DMSS-W and I-Help are two examples where the protocol-based activity is combined with the dialogue-based activity.

Other systems are integrating 3D sensors among other sensors for collecting and analysing raw data for activity recognition in the Ambient Assisted Living (AAL) environment Kitchen As-A-Pal [14, 25] (Figure 1) and Balansera [8]. The data is aggregated and refined for detecting movements and objects in order to associate these to activities defined in the domain ontology. Through the ACKTUS API interpretations are stored in the Actor repository. Ongoing research explores a multiagent system for analysis and provision of support through the different applications.

[4]http://kolwebben.se/
[5]http://tät.nu/

7 RELATED WORK

Recommender systems are widely used in many Internet-based programs [1, 19], where the user suffers from "information glut" and it is difficult to find the correct data he/she wants. In such systems a user profile is typically generated based on the user's historic click behavior. With this use profile, the system can predict which kind of data the user may be interested in and then select the data accordingly, providing a personalized version of the content to this user to save the time otherwise spent on information searching. The purpose can be to help finding the preferred information (i.e., optimizing activity performance), or present advertisements, which may trigger the person to buy a product (i.e. persuasive, encourage a kind of behavior change). A persuasive recommender system for social networks based on argumentation is presented in [4]. The agent in the dementia application exemplified in this article has similar functionality as recommender systems, in that it detects activity by click events. However, considering the semantically enriched information, which can be derived from the click events when interpreting the events through the ontology, our approach moves beyond traditional recommender systems. The interpretations done by the agent can also supplement the agent representing the expert physician in the application, by providing arguments for why the physician may have reasons to change his diagnostic routines [18].

Other agent-based systems have been developed for detecting activity with the goal to optimize activity performance (e.g. [9, 11, 24]). SHARE-IT is a project, which proposes the integration of multi-agent systems with other technologies to build e-tools for people with disabilities and for senior citizens. The tutorial application iTutorial has been developed as part of the assisted living environment in the SHARE-IT project [23]. Based on physical location and a set of individual-specific features (e.g., presence of memory impairment) the support is given in the form of detailed step-by-step instructions on how getting dressed, etc. The support relies on a comparable simple model of the senior citizen, where dysfunction is directly corresponding to type of support to be provided in pre-defined activities of daily living, without adapting to variations of performance. The actor and activity ontology in our work is partly based on a holistic model of ability, dysfunction and health provided by the World Health Organization, which is familiar to health professionals. This differentiates our ontology from e.g., the semantic user model presented in [11], which separates the user ontology from the environment ontology, and matches the two for the purpose to identify handicap situations, mainly due to constraints in the physical environment. Another example of an automated system for older adults with cognitive impairment is presented in [22], which focuses mainly on generating reminders about the activities of their daily living. The approach presented by Erriquez and Grasso serves the individual with tailored advice, also based on predefined user models [7].

8 CONCLUSIONS AND FUTURE WORK

This paper provides a computer-interpretable model for detecting and representing activity in human-agent interaction, which is based on informal models for describing and explaining human activity and earlier research on intelligent agents for promoting wellbeing and health through supporting humans' activities. The results include a common model for storing events generated when a human actor conducts activity, which captures the minimal information needed for advanced analyses of activity progression, performance and fulfilment of the human agent's goals and motives. The model is implemented in different prototype applications targeting the activities in focus for our study.

The categorisation of activities described in this paper based on dependence on i) domain knowledge, ii) social knowledge, or iii) physical environment provides an outline for how to represent, detect and interpret information in order to assess activities meaningful to an individual. We have found it valuable to distinguish between these three categories, since different methods are required for detecting these different activities, for detecting how a person is learning to master the instruments, and for providing support. We are currently exploring how to combine these categories of activity for providing tailored support to humans in their conduction of activity. For instance, the dialogues between the human and software agent may serve as a followup of how the human thinks that their daily life works and of their current emotional, and health status. This subjective view can be complemented with an activity recognition system in the environment. Thus, we expect that the human-agent dialogues may be a means to provide the human control over the AAL environment.

Ongoing and future work include designing the dialogues and the pro-active person-tailored supportive behaviour of the dementia application and the I-Help application. The dementia application is currently being evaluated in clinical practice, and feasibility studies will be conducted also of the other applications within the near future.

REFERENCES

[1] Fabian Abel, Qi Gao, Geert-Jan Houben, and Ke Tao. 2011. Analyzing User Modeling on Twitter for Personalized News Recommendations. In *UMAP*. 1–12.

[2] Juan C. Augusto, Vic Callaghan, Diane Cook, Achilles Kameas, and Ichiro Satoh. 2013. "Intelligent Environments: a manifesto". *Human-centric Computing and Information Sciences* 3, 1 (2013), 12. DOI:http://dx.doi.org/10.1186/2192-1962-3-12

[3] Jayalakshmi Baskar and Helena Lindgren. 2014. Cognitive Architecture of an Agent for Human-Agent Dialogues. In *PAAMS (Workshops) (Communications in Computer and Information Science)*, Vol. 430. Springer, 89–100.

[4] Javier Palanca Cámara, Stella Heras, Vicente J. Botti, and Vicente Julián. 2014. receteame.com: A Persuasive Social Recommendation System, See [6], 367–370.

[5] T. Choudhury, S. Consolvo, B. Harrison, J. Hightower, A. Lamarca, L. Legrand, A. Rahimi, A. Rea, G. Bordello, B. Hemingway, P. Klasnja, K. Koscher, J.A. Landay, J. Lester, D. Wyatt, and D. Haehnel. 2008. The Mobile Sensing Platform: An Embedded Activity Recognition System. *Pervasive Computing, IEEE* 7, 2 (April 2008), 32–41. DOI: http://dx.doi.org/10.1109/MPRV.2008.39

[6] Yves Demazeau, Franco Zambonelli, Juan M. Corchado, and Javier Bajo (Eds.). 2014. *Advances in Practical Applications of Heterogeneous Multi-Agent Systems. The PAAMS Collection - 12th International Conference, PAAMS 2014, Salamanca, Spain, June 4-6, 2014. Proceedings*. Lecture Notes in Computer Science, Vol. 8473. Springer.

[7] Elisabetta Erriquez and Floriana Grasso. 2008. Generation of Personalised Advisory Messages: An Ontology Based Approach. In *CBMS*. IEEE Computer Society, 437–442.

[8] Esteban Guerrero, Juan Carlos Nieves, and Helena Lindgren. 2016. An activity-centric argumentation framework for assistive technology aimed at improving health. *Argument & Computation* 7, 1 (2016), 5–33.

[9] David Isern, David Sánchez, and Antonio Moreno. 2010. Agents applied in health care: A review. *I. J. Medical Informatics* 79, 3 (2010), 145–166.

[10] Rebecka Janols, Esteban Guerrero, and Helena Lindgren. 2017. A Pilot Study on Personalised Coaching to Increase Older Adults' Physical and Social Activities. To appear.

[11] Rachid Kadouche, Mounir Mokhtari, Sylvain Giroux, and Bessam Abdulrazak. 2008. Personalization in Smart Homes for Disabled People. In *Proceedings of the 2008 Second International Conference on Future Generation Communication and Networking - Volume 02 (FGCN '08)*. 411–415.

[12] Victor Kaptelinin. 1996. Activity theory: Implications for Human-Computer Interaction. In *Context and Consciousness. Activity Theory and Human Computer Interaction*, Bonnie A. Nardi (Ed.). MIT Press, 103–116.

[13] Catriona M Kennedy, John Powell, Thomas H Payne, John Ainsworth, Alan Boyd, and Iain Buchan. 2012. Active assistance technology for health-related behavior change: An interdisciplinary review. *Journal of Medical Internet Research* (2012).

[14] Helena Lindgren, Jayalakshmi Baskar, Esteban Guerrero, Juan Carlos Nieves, Ingeborg Nilsson, and Chunli Yan. 2016. Computer-Supported Assessment for Tailoring Assistive Technology. In *Proceedings of the 6th International Conference on Digital Health Conference (DH '16)*. 1–10.

[15] Helena Lindgren, Lillemor Lundin-Olsson, Petra Pohl, and Marlene Sandlund. 2014. End Users Transforming Experiences into Formal Information and Process Models for Personalised Health Interventions. *Studies In Health Technology And Informatics* 205 (2014), 378–82.

[16] Helena Lindgren and Ingeborg Nilsson. 2013. Towards User-Authored Agent Dialogues for Assessment in Personalised Ambient Assisted Living. *International Journal of Web Engineering and Technology* 8, 2 (2013), 154–176.

[17] Helena Lindgren, Patrik J. Winnberg, and Peter Winnberg. 2011. Domain Experts Tailoring Interaction to Users - An Evaluation Study. In *INTERACT (3) (Lecture Notes in Computer Science)*, Pedro Campos, T. C. Nicholas Graham, Joaquim A. Jorge, Nuno Jardim Nunes, Philippe A. Palanque, and Marco Winckler (Eds.), Vol. 6948. Springer, 644–661.

[18] Helena Lindgren and Chunli Yan. 2015. Detecting Learning and Reasoning Patterns in a CDSS for Dementia Investigation. *Stud Health Technol Inform* 210 (2015), 739–42.

[19] Jiahui Liu, Peter Dolan, and Elin Ronby Pedersen. 2010. Personalized News Recommendation Based on Click Behavior. In *IUI*. 31–40.

[20] Viviana Mascardi, Valentina Cordì, and Paolo Rosso. 2007. A Comparison of Upper Ontologies.. In *WOA*, Vol. 2007. 55–64.

[21] M. Philipose, K.P. Fishkin, M. Perkowitz, D.J. Patterson, D. Fox, H. Kautz, and D. Hahnel. 2004. Inferring activities from interactions with objects. *Pervasive Computing, IEEE* 3, 4 (Oct 2004), 50–57. DOI:http://dx.doi.org/10.1109/MPRV.2004.7

[22] Martha E. Pollack, Laura Brown, Dirk Colbry, Colleen E. McCarthy, Cheryl Orosz, Bart Peintner, Sailesh Ramakrishnan, and Ioannis Tsamardinos. 2003. An Intelligent Cognitive Orthotic System for People with Memory Impairment. *Robotics and Autonomous Systems* (2003).

[23] Carolina Rubio, Roberta Annicchiarico, Cristian Barrué, Ulises Cortés, Miquel Sánchez-Marré, and Carlo Caltagirone. 2010. iTutorials for the Aid of Cognitively Impaired Elderly Population. *eHealth 2010* (2010), 303–310.

[24] Saguna Saguna, Arkady Zaslavsky, and Dipanjan Chakraborty. 2011. Complex Activity Recognition Using Context Driven Activity Theory in Home Environments. In *Smart Spaces and Next Generation Wired/Wireless Networking*, Sergey Balandin, Yevgeni Koucheryavy, and Honglin Hu (Eds.). Lecture Notes in Computer Science, Vol. 6869. Springer Berlin Heidelberg, 38–50. DOI: http://dx.doi.org/10.1007/978-3-642-22875-9_4

[25] Dipak Surie, Helena Lindgren, and Arslan Qureshi. 2013. Kitchen AS-A-PAL: Exploring Smart Objects as Containers, Surfaces and Actuators. In *Ambient Intelligence - Software and Applications*, Ad Berlo, Kasper Hallenborg, Juan M. Corchado Rodriguez, Dante I. Tapia, and Paulo Novais (Eds.). Advances in Intelligent Systems and Computing, Vol. 219. Springer International Publishing, 171–178.

[26] D.N. Walton and E.C.W Krabbe. 1995. *Commitment in dialogue: Basic concepts of interpersonal reasoning*. SUNY Press.

[27] Chunli Yan, Juan Carlos Nieves, and Helena Lindgren. 2014. A Multi-agent System for Nested Inquiry Dialogues, See [6], 303–314.