Personalisation and User Models for Support in Daily Living

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ABSTRACT
In recent years, the interest in developing personalised applications for home environment has grown since it has a wide reach in helping people in their daily activities. However, for our purposes the concept activities of daily living also need to include work and leisure activities not necessarily performed in home environments. In this article, we describe an ongoing effort to develop a generic framework for assessing ability and tailoring of support applications in the health domain. We also give an overview of the approaches that have been adopted for personalisation and user modelling to various application areas. Suggestions of future development are provided.

KEYWORDS
Personalisation, User modelling, User models, Clinical decision-support systems, Multi-agent systems, Ambient intelligence, Human computer interaction, Adaptive hypermedia system, E-learning, Adaptive education systems, Machine learning, Intelligent tutoring systems

1. Introduction

Web-based applications have users who have different knowledge, learning styles, interests, background and preferences regarding information presentation over the Internet. This has paved way to research on interfaces that can be designed to recognize the goals and characteristics of the user and adapt accordingly. In order to achieve adaptability of personalised information, it is important to observe the user's behaviour, and make predictions based on those observations. The information pertaining to individual user obtained from such observations is known as a *user model* (e.g., [1]). A user model, or a simple user profile, may consist of information collected by filling questionnaires, by observing user-actions, or by making inferences. *Personalisation* aims at providing users with the content that they need without necessarily requiring the users to specify it explicitly [2].

Applications developed for smart homes or for the healthcare domain need to be adaptable to the needs of an individual. Therefore, customizing the environment services according to the user preferences is very important. The personalisation for dependent people is a difficult task, which should involve a team of disciplines such as ergonomics, occupational therapy, design, engineering, medicine etc. Furthermore, the development of tailored educational systems for knowledge workers such as medical or mining personnel also requires knowledge in the different knowledge domains.

In the work on developing knowledge-based applications tailored to individuals in three different knowledge domains, a common user model has been synthesized based on pilot projects [3]. The pilot projects have been targeting the diagnosis of dementia, monitoring health in the mining and construction industries and activity support for older adults in their home environments. The common user model is implemented as an RDF/OWL ontology functioning as part of ACKTUS, a knowledge and interaction modelling prototype application for the health domain. The knowledge and interaction is primarily modelled by domain experts. Consequently, focus has been on their explicitly defined user scenarios where they adapt the knowledge to different characteristics by using simple rules. However, there is a need to extend the tailored support by supplementing the adaptability of ACKTUS applications with adaptive functionality. There are three particular goals for this work: 1) to tailor support to an individual health professional's diagnostic reasoning; 2) to tailor support to an individual mining worker based on a combination of self-assessed complaints, body measures and factors obtained in his/her work environment; and 3) to tailor support for an individual in their home environment based on a combination of self-assessments and activity recognition and evaluation. In this work, focus is set on the third goal, however, examples are provided also for the first two. The purpose of the work presented in this paper is to present and evaluate to what extent the current user model applied in ACKTUS is sufficient for the purpose and in what aspects the model needs to be developed. For this purpose, existing approaches to the task are being explored and evaluated.

This paper is organised as follows. Section 2 describes ACKTUS, which is a prototype to be used by domain professionals for modelling personalised behaviour and user models. Section 3 describes personalisation research similar to the approach presented in this paper. In Section 4 the results are summarised and future work is outlined.

2. ACKTUS - a Tool for Modelling Personalised Behaviour and User Models

Empirical studies of three different knowledge domains generated features essential for the different knowledge domains in the personalisation of support applications [3]. These features were categorized and interpreted using activity theory [4] and existing medical and health terminologies. A model, which functions as a generic model common for the different domains, was developed as core ontology. The backbone of the ontology utilizes activity theoretical models for human in activity and the ACKTUS user model is partly built upon the International Classification of Functionality, Ability and Health (ICF) developed by WHO[1]. The core ontology is extended in the modelling of domain specific content by the domain experts. In this modelling, the domain experts can construct user models by combining features as RDF-tuples using dedicated user interfaces (Figures 1-6).

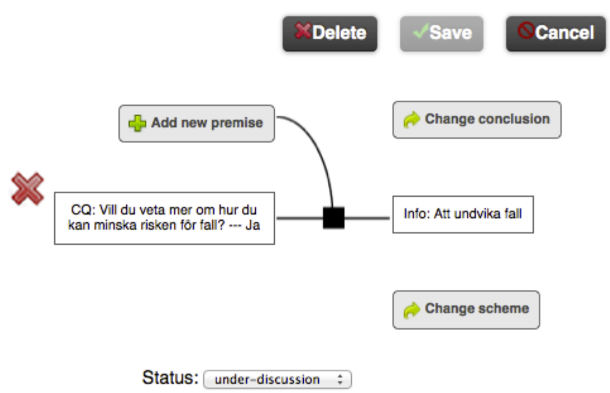

Figure 1. The editor for composing rules. An example of an advice to be given to an end user if interest is expressed.

When the user provides information in an end-user application, the application requests further information depending on which features are provided, following the thematic protocols of information collection defined by the domain experts. Based on this, the user profile is built.

In the system's dialogues with the user, the user is provided responses from the system in the form of 1) suggestions of decisions, 2) advices and 3) suggestions of actions to make. Currently, the actions are formally defined as ACKTUS assessment protocols.

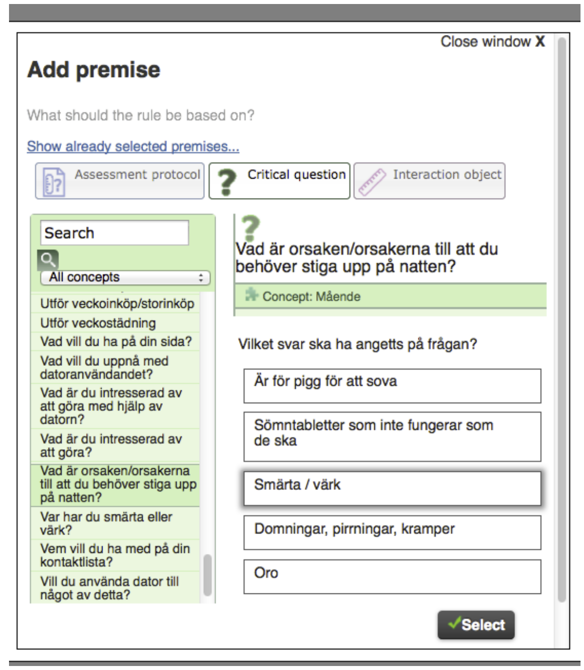

Figure 2. The editor for composing rules to be used in assessments. A premise can be added in this example.

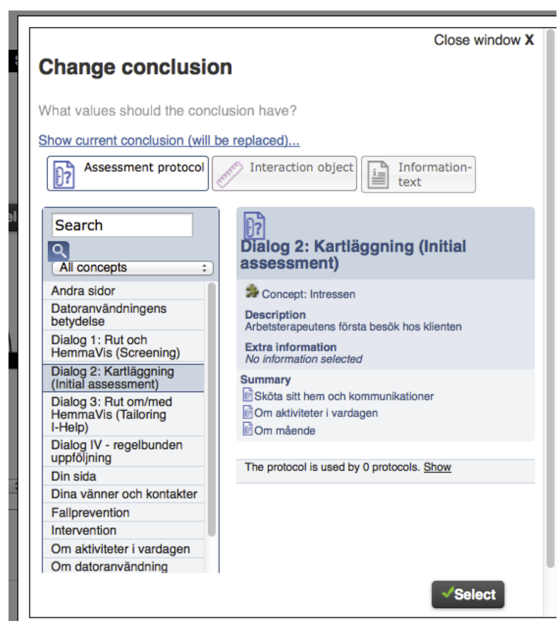

Figure 3. Example of an attempt to change the consequent of a rule to an ACKTUS assessment protocol.

[1] http://www.who.int/classifications/icf/en/

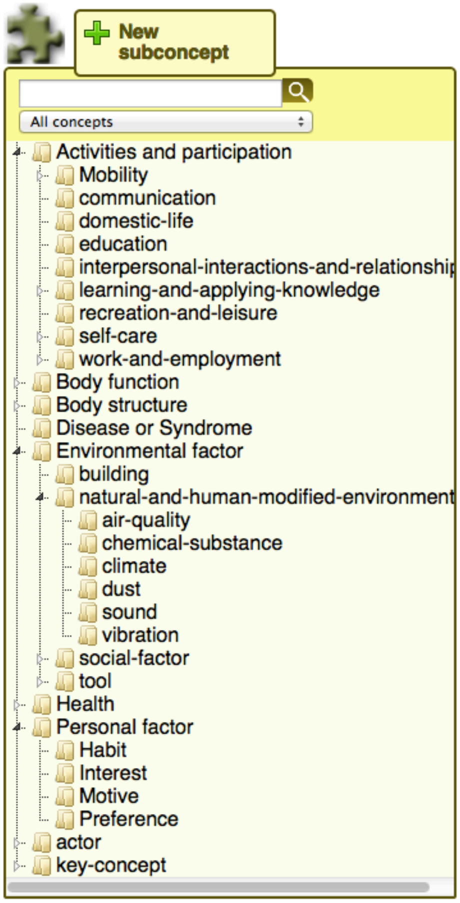

Figure 4. An overview of the nodes in the core ontology that builds the user models. The domain experts can refine the conceptual model by creating sub-classes so that it suits the domain.

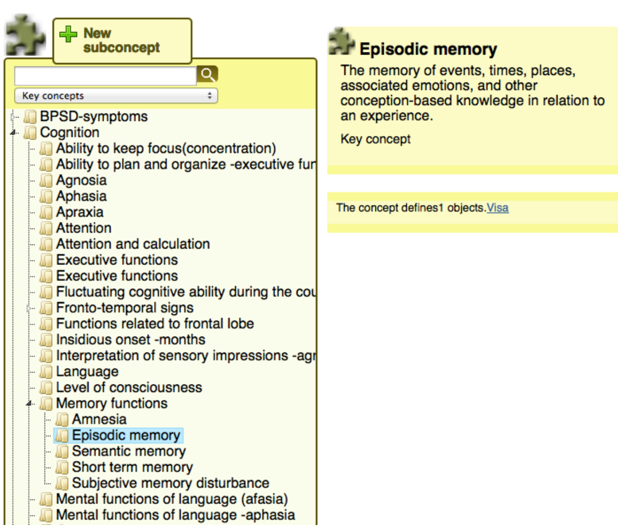

Figure 5. Example of a sub-tree of concepts particular to the dementia domain specified by domain experts. Definitions or explanations can be added, used for educational purposes in end user applications.

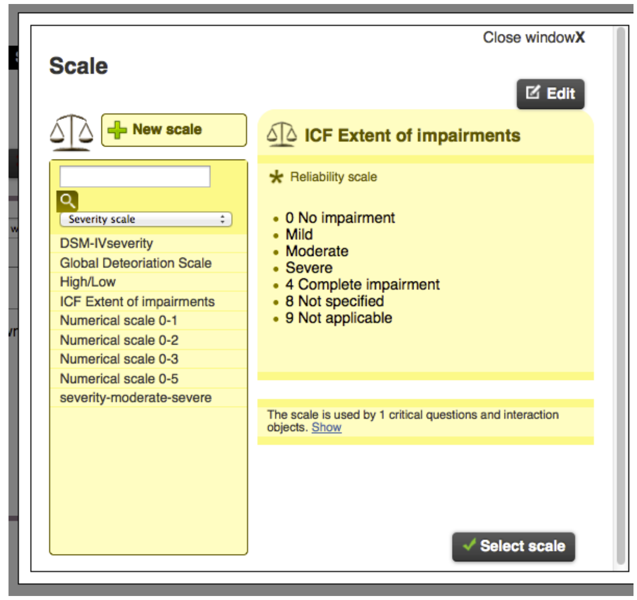

Figure 6. Scale editor that is used to define sets of values and associate it to ACKTUS objects such as questions. In the example the ICF scale about the extent of impairment is shown.

Features that relates to the physical home environment (e.g., in terms of *spaces*) can be captured by the ACKTUS ontology at a generic level using the *building* class (Figure 4). Furthermore, smart objects can be considered as being *tools*, thus falling under this concept. Activities fall under the *Activities and Participation* class, following the ICF categorization as basic structure. Concerning ability to execute basic level tasks, such as handle doors, windows, etc., such features can be added to the activity class that concerns *mobility*. Limitations in ability that are caused by the characteristics of the physical environment need to be assessed in each individual case, since each individual's environment is unique. In [5] this was done by an occupational therapist. In our work presented in [6], two occupational therapists and a nurse assessed the older adult's life situation in our case scenario using the concepts (e.g., Figure 5) and scales (e.g., Figure 6) of assessment instruments typically used in their daily work.

The core ontology implements in addition to the user model the components of reasoning in the form of an argumentation framework. The argument interchange format (AIF) is used for visualising and typing different arguments and argumentation schemes [7]. Preferences can be expressed, e.g., about which knowledge sources to be used (clinical guidelines etc.).

2.1. Extending ACKTUS Applications with Adaptive Functionality in three Application Domains

A pilot project with the purpose to investigate needs and motives for tailored web interfaces to older adults for accomplishing activities that they wanted to perform generated a generic model of purposeful activity [8]. The main needs behind web-supported activities that were identified were i) feeling safe and secure (in particular as part of a social context), ii) having knowledge and control (e.g., keeping up with news), and iii) feeling good, healthy, engaged, active, having fun (e.g., performing activities in fields of interest). These themes were common to the participants and have been in our work so far considered generic enough to provide a sufficient base for personalisation in a home context. What is evident is that an important part of an input to the personalisation has to be the self-assessed view on activity performance and goal satisfaction. This part can also be achieved using ACKTUS [9]. However, the potential pro-active behaviour to invoke assessment and adapt to changing needs and abilities is lacking in the ACKTUS applications. This is also seen in application domains other than support systems for older adults. Therefore, we present ongoing research and some results in the following sub-sections.

2.1.1 Personalisation for Supporting Older Adults in Home Environments

Activity recognition is an important and interesting challenge to address in dealing with pro-active assessment and adaptation to changing user needs and abilities within a smart home. Activity recognition facilitates implicit data collection on: How everyday activities are performed quantitatively? For instance, how mandatory actions like turning off the stove after cooking and locking the door before leaving the home are performed? How often such mandatory actions are forgotten? What are the activities that are usually completed successfully? The list of activities that require further assistance and adaptation of the environment, etc. can be analysed. The everyday activities that are in focus for our work are higher level activities such as preparing breakfast that involves planning, organizing, decision making, allocating time, using physical/virtual equipments and taking part in social interaction. Events like forgetting to take the milk packet from the refrigerator and placing it on the dining table are modelled as actions (some could be mandatory actions). The activities are part of a 24-hours activity loop making it possible to monitor the activities and the organisation of activities performed by an individual.

We use a case scenario created based on the mentioned pilot project, which describes an older woman with some difficulties in her daily life and in her home environment [10]. We explore and describe the case study as four distinct but related activities: 1) initial assessment, 2) referral to physician, 3) determine interventions, 4) apply interventions in the daily life of the individual including a continuing assessment (and follow-up), and 5) a renewed assessment. A software architecture was proposed in [11], utilizing results from the Easy ADL project [12]. The conceptual design of an activity recognition system is being formed in a living laboratory home environment [13]. The living laboratory home environment to be used comprises of smart objects that are augmented with ambient intelligence technologies. The smart objects apart from their primary functionality are expected to provide additional virtual functionalities like sensing user interaction with the object, internal state changes caused by such interaction, exchanging collected sensor readings with trusted applications like the ACKTUS application, and providing access/control to virtual information through multiple modalities depending on the context. Further information about the underlying technological infrastructure: ecology of smart objects and a personal activity-centric middleware to manage those smart objects is available [14]. The data collected from sensors in smart objects will be interpreted into activities and matched to the semantics of the ACKTUS user model [11]. The idea is to synthesize the explicit knowledge and interaction designed by the domain experts with the implicit knowledge obtained from the smart home.

2.1.2 Personalisation for Supporting Mining Workers in their Work Environments

An ongoing project aims at supporting the workers in mining and mining-related work environments in valuing the risks of their work situation and create awareness in the individual about how he/she can decrease risks. The purpose is to evaluate the vibration, dust and skin related problems from the data collected when the worker uses support applications. The evaluation is done according to algorithms defined by experts in the field based on available knowledge. This could possibly lead to taking precautions such as wearing a mask if the air contains harmful components in the form of dust such as Lead (molecular formula: Pb). A prototype of a "vibration application" called *ArbetsVis* has been developed and will be evaluated in wider use during 2012. The application provides tailored calculations of risks and advices about what can be changed in the work context to reduce the vibration exposure [10].

In addition to vibration, mining workers are often exposed to dust of different types that may be hazardous depending on the level of exposure and the history of exposure. Another purpose is to provide the worker tailored assessment of risk and advice about preventing medical conditions due to the exposure. In a user model that can provide the base for such support, both information about the individual such as measures obtained by blood tests and/or pulmonary tests is important, as well as information about the presence of hazardous dust particles in the work environment. Time is also an important parameter in the calculations of the risk, e.g., time periods when the work tasks are conducted in dusty environments.

As part of this ongoing work, domain experts are modelling the explicit knowledge using ACKTUS. This includes both the medical experience they possess and the national guidelines governing what thresholds of exposure are allowed in work environments. In their work to identify key features of user models, they use the concept editor that allows them to categorise professions, machines, etc. so that the conceptual model of vital part of their work environment becomes familiar to an end user (Figure 4). Concepts that are already defined in ICF and reused in the project are concepts that relates to a physical environment such as *vibration*, *dust*, *chemical substance*, etc. The participating domain experts define the sub-categories of these generic concepts that are considered relevant and useful and form a more specific knowledge model.

In collaboration with one of the mining industries, a test repository is being created with measures of lung capacity and presence of lead in blood samples related to fictive individuals, similar to the database they use in the in-house medical service. Furthermore, it is investigated in which way measures of the presence of dust can be accomplished in the participating mining industries. Consequently, further analyses will be needed as part of future work to enable situated support to individuals based on such information.

2.1.3 Personalisation for Improving Diagnostic Reasoning in Health Professionals

There is an urgent need to provide medical professionals tools for verifying decisions, incorporating new research-based knowledge and monitoring a personal continuing medical education, as part of everyday practice in their meeting with patients. Studies have shown that 75% of dementia patients do not receive a dementia diagnosis at their first visit to a physician. Studies have also shown that introducing a clinical decision-support system for supporting dementia diagnosis can change work routines, increase teamwork and detect lack of knowledge in medical professionals [15-16].

Therefore, allowing for the medical professional to keep control both over his/her own (developing) "knowledge-base" as well as other actors' is an approach we apply in an ongoing research project. An additional motive is to provide methods for detecting emerging knowledge as interaction takes place, also at stages before the knowledge has become established as "evidence-based" medical knowledge. In this interaction, detecting patterns of reasoning in relation to individuals' knowledge and patient cases is central. For these purposes we intend to use repositories of data relating to patent cases and their physicians' investigations to explore the potentials in modelling support in the form of tailored, personalised dialogues [17].

2.2 Towards a Multi-Agent System for Personalisation

The agent paradigm is receiving increased focus and application to health care. There are particular benefits when using a multi-agent system (MAS) perspective on a distributed and collaborative use environment utilizing mixed-initiative functionality. Agents have autonomy to a certain extent to behave pro-active taking initiatives based on their repository of beliefs about its environment (e.g., [18]).

As described earlier, we take a persona and a case scenario as starting point for development of an ambient assisted living environment [11]. An analysis of the scenario generated an outline for a MAS design. We analysed the different dialogues exemplified in our scenario, interpreted them as *dialogue games*, and categorised them into three types of dialogues described by Walton [19]: *information seeking*, *inquiry* and *deliberation* dialogue. They differ by their purpose where information seeking aims at collecting information, inquiry dialogues aim at collaboratively create new knowledge and a deliberation dialogue aims at collaboratively decide upon an action to be performed.

For illustrating the dialogues in our use scenario in the development sessions with domain experts, we use an algorithm for executing the information seeking dialogues and for simulating the inquiry and deliberation dialogues. The algorithm only makes use of ACKTUS assessment protocols, their content, their associated rules and their consequents as dialogue flows structured by the domain experts in the modelling sessions. The dialogues were used in the sessions for the domain experts to evaluate the effects of their modelling [9].

A formal argumentation-based framework and the agent interaction protocols need to support the identified types of dialogues. Furthermore, we identified the following speech acts or moves to be performed by each agent: *open*, *ask*, *assert* and *close*. Consequently, the context-based inquiry dialogues proposed in [17] need to be extended to incorporate critical questions based on the ACKTUS critical questions and reasoning contexts to achieve the *ask* move. Initial results are presented in [20].

3. Related Work

Research on personalisation similar to the work presented in this paper has been carried out by Kadouche et al [5], with the *Semantic Matching Framework* (SMF) defining the user limitation capabilities and provides adapted process to personalise the service delivery. The core functionality of SMF is based on semantic matching between the user model and the environment model. The user model characterises user factors, for instance his name, his preferences and capacities, defined as user's attributes. The environment model describes environment factors it specifies devices (e.g., doors, windows, sensors, etc.), defined as "effectors", each effector contains a set of characteristics defined as environment's attributes, for instance: required force to open the door, the door size, etc. These factors are quantified to formalise the relation between the user's attributes and the environment's attributes which brings out the handicap situation for each user on his daily living activities [5]. The framework has been designed with experts in psychology and computer science [5].

A review of agents applied in health care is provided in [18] where the following examples are given. The *Context-aware Hospital Information System* (CHIS) is a MAS, which provides intelligence and proactive capabilities to healthcare environments furnished with ubiquitous computing and medical devices [21]. Some degree of personalisation is accomplished in this system. The interaction with the system is based on the user's permission in performing the activities. Another example of a MAS that supports personalisation is the project Health Care Services (HeCaSe2) [22], which offers healthcare services to the users (patients and practitioners). In this system, a single agent is associated to each user and the knowledge that is endowed to the user is based on the user's preferences and supports personalisation.

In the past decade, numerous studies on user modelling have been conducted by researchers [23]. The approaches have been discussed with respect to its methodology adopted for the user information. User profiles have been used in the healthcare domain to provide management and retrieval of person or patient's physiological data [24]. In a smart home, a cooking guide is a true effort towards the contextual rich dynamic proactive knowledge-based application. A proactive knowledge base is built from the sensors augmenting the objects in use, surrounding devices and user profiles. Sophisticated data mining algorithms, rule based mechanisms and user model learning techniques facilitate contextual awareness and adaptability towards the assistance and end user ambient support [25]. There are many techniques available to model an adaptive web system such as *feature-based modelling* and *stereotype-based modelling*. Feature-based modelling attempts to model specific features such as individual user's knowledge, interests, goals etc. The majority of modern web systems use the feature-based approach to represent and model information about the users such as Bayesian Student Models (BSM) in which the student features are modelled and parameters of the model are obtained [26]. An example of the stereotype-based model is the *User Modelling and Profiling Service* (UMPS), which provides the methodology for context dependent personalisation and adaptivity of applications and services in the Amigo environment [27]. Normally, a stereotype model ignores the features and uses the stereotype as a whole. In UPMS the user profiles are built first based on stereotypes and explicit user input, and in the second step these profiles are refined using the interaction/context history. User modelling, also known as user profiling is the key in the development of interactive software systems that are able to identify and to adjust themselves to the needs of particular user at every stage of use, irrespective of these user's knowledge whether they are experts or beginners.

User modelling has evolved from representation of groups of users using a certain system in certain conditions, to personalisation of these systems towards individual user's preferences and requirements. In the case of ambient intelligent systems personalisation applies to different system components and application domains, particularly to user interfaces, for example, graphical content, gesture and voice based and content presentation.

Personalisation depends upon the initial knowledge of the system about its potential users and the mechanism used to learn user's behaviour and preferences [28]. It is also dependent on the system's use context. Thus the system needs to be adaptable to the context as well. In the following sub-sections an overview is given of different real world applications making use of personalisation and user modelling, categorised by their purpose and context of use. We limit our focus to general assistance, smart home environments for supporting activities of daily living (ADL), intelligent tutoring systems and personalised systems for promoting health during work or leisure time.

3.1 Living Assistance Support Systems

Research related to living assistance broadens the scope of support systems. Such systems can be for indoor and outdoor assistance. Systems for indoor living assistance work in a well-defined locality, for example home, car, hospital or elderly care homes. Appropriate sensors, hardware and software can be installed for the suitable environment. The latter could be developed for activities such as shopping or travelling.

According to Nehmer et al [29], three types of services could be provided by a support system, namely, emergency treatment, autonomy enhancement and comfort. The emergency treatment plays the most important role as it aims at the early prediction of and recovery from critical conditions that might result in an emergency situation and safe detection and alert propagation of emergency situations. Examples are when patient suddenly falls, strokes etc. Autonomy enhancement services denote all services that make it possible to abandon previous manual care given by medical and social care personnel or relatives and replace it by appropriate support system. The best example for such assistance is a cooking assistance system for people with visual defects [29]. The appropriate sensors attached to a stove may enable them to cook safely, automatically detect if the stove is switched on for long time without any purpose and alert the user.

3.2 Assisted Living within a Smart Home

Personalisation and user modelling plays a central role in designing smart homes that enable elderly persons to live a longer and more independent life at home (in accordance with the concepts of successful ageing and assisted cognition). EU research programs like the Ambient Assisted Living (AAL) [30] are moving in this direction. Since life expectancy is increasing and more elderly people would populate the society in the future, efforts like AAL are necessary to provide a good quality life for the elderly. Elderly people are also prone to physical and cognitive disabilities that introduce a need to personalise and adapt their smart homes. Independent living means that the elderly person must be able to do basic activities of daily living like taking a shower, eating and dressing, and more complex activities of daily living like preparing a shopping list and cooking food. Activity recognition plays an important role in enabling independent living of elderly within their smart home. Everyday activities performed by different individuals within a home environment vary significantly, introducing a need to be aware of the user's identity, preferences, capabilities, likes and limitations. Also, there are variations in how certain activities are performed by an individual depending on the contextual conditions. Solutions that lack personalization affect the user experience provided by smart homes.

Smart homes for people with disabilities are an objective of many research efforts. The *Nursebot* project [31] is aimed at developing mobile robotic assistants that support elders in performing their activities of daily living (ADL) at home. The *SmartBo* project [32] focuses on elders with mobility impairments and cognitive disabilities while the *Gloucester Smart House* [33] focuses on people with dementia. An automated hand-washing assistant for people with dementia is being developed [34]. Automated health monitoring and anomaly detection for cognitively and physically challenged people using machine learning algorithms that can model their behaviour is also described in research [35]. AAL within the CareLab [36] has focused on monitoring and coaching elderly people to enable them to maintain an independent lifestyle by focusing on their feeling of safety, cognitive prosthesis and social interaction.

The easy ADL ecology [12] is a smart home that models a user's situation, activities and interaction possibilities with the long-term goal of providing support for mild-dementia patients. A human agent's body is used as a starting point to determine: a) the objects that are present in close proximity to the user useful in modelling their situation [37]; b) the objects that are manipulated by the user in modelling the activities performed [14]; and c) the interactive devices in the close proximity are useful for timely delivery of assisted living services [13].

A kitchen environment could be viewed as the heart of a home comprising of several household objects, home appliances and furniture facilitating numerous everyday activities with varying complexities. A smart refrigerator capable of presenting personalized information, intelligently evaluating its contents and informing about missing ingredients based on user profile or their potential future cooking activity is useful [38].

A bathroom is another important space in a home where self-care activities are performed. A shower cabin or a tub that adapts the water temperature based on user profile could be an automated service provided by the smart home. Brushing teeth, combing hair, shaving and applying make-up usually takes place inside a bathroom in front of the bathroom mirror. Assisted living services could be incorporated within the so-called "smart mirror" augmented with ambient intelligence technology that identifies the user (for instance, based on the tooth brush or the shaving razor used). The smart mirror apart from its original functionality of reflecting a person's image also presents personalised information relevant to that person. Examples include presenting the day schedule, news, melodies to remove stress and weather information. Additionally, by standing on a smart carpet in front of the mirror, the person's weight information and cardiovascular health status using existing medical data could also be presented on the smart mirror.

3.3 Intelligent Tutoring Systems

The majority of intelligent tutoring systems (ITS) focused on representing two types of domain knowledge: conceptual and procedural knowledge. A large class of ITS known as "tutors" focus on helping users solve educational problems, and thus rely on procedural knowledge of either problem solving or evaluation nature [39]. The use of conceptual knowledge is shared by almost all non- educational systems, which also focus on guiding the user to the most appropriate content.

The tutorial application iTutorial has been developed as part of an assisted living environment in the Share-it project [39]. 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.

3.4 Intelligent Health Promotion Support Systems

Another application area attaining growing research interest is to enhance the work environment such that the risks, health hazards, physical and psychological strains could be analysed and predicted to facilitate a better work environment. An example of this is the application for stress diagnosis developed by Begum et al [8]. They present a computer-aided decision support system for analyzing and diagnosing stress-related disorders based upon finger temperature signals where the finger temperature measurement is taken using a temperature sensor to establish an individual's stress profile. The functionality of the system lies in solving a new problem case by using solution of solved cases from the past (case-based reasoning), which often require adaptation to find a suitable solution for the new case.

A wide range of applications target behaviour change in users to increase healthy living by persuading individuals to exercise, eat healthier, etc. One example is the work by Grasso and Erriques [40] where they used an ontology that included both person specific factors, activities and types of responses aimed at giving encouraging arguments to pursue a healthier lifestyle.

4. Summary and Future Work

ACKTUS as tool for modelling user information and for personalisation of support applications has been presented. Motivations to personalise support applications for a variety of daily living activities have been described: work and education (monitoring health in the mining work environment and for supporting dementia diagnosis), leisure and social activities (older adults' home environment), personal and home care (older adults' home environment).

For the purpose to provide an individual computer-based support in daily living for increasing autonomy, security, health, social inclusion and quality of life, a holistic view on the individual's situation needs to be adopted. The wishes, needs and abilities of the individual need to be assessed to optimize the design of the tailored support. Furthermore, the assessments need to be done continuously, to adjust the tailored support to changing needs, abilities, wishes and contextual factors. Therefore, we integrate *assessment* into a framework for developing and maintaining ambient assisted living with personalised support. This will be accomplished by using a combination of methods where the professional assessments done by health care professionals, play a key role.

An overview of the existing approaches presented in literature has been provided, which have been adopted for personalisation and user modelling for various domains. The purpose was to compare the applied methodologies with the ongoing effort to develop a generic framework for assessing ability and tailoring of support applications in the health domain (ACKTUS). Several related projects use similar technology and ambition, that is, to provide meaningful support in daily living to older adults, or tailored support for learning and decision-making. However, none of the approaches we found aimed at the holistic assessments that ACKTUS targets, neither allowing the domain professionals to conduct the modelling and application of an ontology and its content in user cases for evaluation purposes. Moreover, the novel approach to use a common core ontology for modelling support for various every day activities and knowledge domains, including work-related, was presented.

Ongoing and future work includes among other tasks the investigation of how data obtained in a home or work environment can be refined into information that can be interpreted as qualitative knowledge about an individual's ability to perform activity, and providing situated risk assessments. In this context, an important research question is how to create a realistic mapping between existing scales for measuring user ability (e.g., ICF-scales, ADL-scales, the AAIMA-protocol [8]) and the sensor information obtained from smart objects. The determination of what state changes to objects are important, what does such state changes mean when interpreted according to the existing scales, how to model everyday activities such that the activity recognition models are comparable to the models described by the existing scales, are important aspects to dig deeper in adapting the existing living laboratory home environment to a personalised environment for conducting pro-active assessment of older adults' abilities.

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