ACKTUS - A Platform for Developing Personalized Support Systems in the Health Domain

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ABSTRACT

This paper presents ACKTUS, a semantic web platform for modeling and managing knowledge integrated in support systems for health care, and for designing the interaction with the end user applications. A key purpose is to allow the domain experts to collaboratively model the knowledge content and tailor interaction to users. Therefore, the development has been done in a process of participatory action research where domain experts have contributed to the design and re-design of ACKTUS while they have been modeling the content and behavior of end-user applications. The ontology that serves as the knowledge structure in the system integrates the user model, modality values, clinical practice guidelines and preferences, in the form of schemes and scheme-nodes (arguments) in an argumentation framework, partly by integrating the argument interchange format. User studies have shown that ACKTUS can be used for the intended purpose by domain professionals not familiar with knowledge engineering tasks. Moreover, the platform functions as a research infrastructure for health researchers in their development and evaluation of new ICT-based interventions targeting improved health.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation**]: Group and Organization Interfaces; I.2 [**Artificial Intelligence**]: Miscellaneous

Keywords

Cooperative design; Knowledge engineering; Interaction design; User modelling; Personalisation; Ontology; Semantic Web; Decision-support systems; e-health

1. INTRODUCTION

Transforming medical knowledge residing in individual experts and in sources of evidence-based medical studies to formal structures to be integrated in intelligent support systems is a challenging task in the development of clinical decision support systems (CDSS) [30]. There is a trade-off between designing a knowledge building and knowledge maintenance environment in which the clinician can easily provide expert knowledge, and a formalization environment using advanced knowledge structures for capturing modalities, handling negations, ambiguities, lack of information, etc. Using semiformal or formal structures for knowledge acquisition often requires that the medical personnel need to be educated in using the systems and assigned significant amount of time to spend on entering the necessary knowledge (i.e., the knowledge acquisition bottleneck) [25, 27, 26, 5].

The problem is similar when experience-based knowledge is to be communicated by e.g., construction and mining workers, older adults or adolescences in a participatory design process. There is a growing understanding that the future user group of an application needs to be actively involved in the development process, partly, for increasing the motivation for using the resulting application. This is particularly essential when *behavior change systems* are developed aiming at improving people's health and daily routines [21, 6, 3, 20].

In order to provide an individual appropriate support for accomplishing a task, which the person values as important and possibly difficult to accomplish, the personal factors such as the individual's needs, preferences, ability, knowledge, etc. are vital to take into consideration. Methods for *personalization* and *adaptation* are useful for both a domain professional in daily work situations and an older adult in an ambient assisted home environment [10, 8, 24].

The complexity of a medical domain such as the the dementia knowledge domain creates a need for assessing the patient's difficulties from different viewpoints and using different professional competences. The individual users of a decision-support system integrated in this use context have different professional backgrounds, different preferences regarding, for example, which guidelines to use and different needs for individually tailored support [11]. It is important to create structures that allow the end user in clinical practice to adjust the support based on preferences, local policies and local work routines [11]. This adaptation includes functionalities such as which sources to base reasoning on, which assessment instruments to use, allow deviations from guidelines in patient cases but also provide means to add motivations for alternative interpretations.

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In order to address the need for new tools, which are easy and flexible to use by professionals who are not necessarily familiar with knowledge engineering or interaction design tasks, we present in this paper ACKTUS (Activity-Centered Knowledge and interaction modeling Tailored to USers), a web-based platform for developing knowledge-based applications.

The article is organized as follows. The methods for the development of ACKTUS (Section 2.1), modules of the ACKTUS platform (Section 2.2), its interaction design and functionality and their evaluation (Section 2.3) are described the following section. ACKTUS contributions are compared to related work in Section 3 and the paper ends with some conclusions and directions for future work.

2. ACKTUS

The main requirements that ACKTUS needs to meet are supporting collaborative knowledge building and maintenance of knowledge, and supporting the development of personalized support, including support for learning, reasoning and decision making. Consequently, essential requirements for ACKTUS are simplifying the entering of knowledge without loosing significant characteristics in the knowledge; and functionality that take individual preferences, motives, experience, physical complaints, professional roles and work environment into consideration for personalization and adaptation purposes.

In the following sections the methods for developing ACKTUS and the modules and functionalities of ACKTUS will be further described.

2.1 Methods

A participatory action research process has been applied in the development of ACKTUS, which has involved domain experts and potential user groups from different application domains (e.g., [1]). The application domains include:

- *investigation and management of dementia diseases*: two geriatricians and additional 25 physicians have been involved [11, 20],
- *fall prevention in older adults*: five physiotherapists and 17 older adults have been involved [14],
- *intelligent home environments for older adults*: four occupational therapists have been involved [15, 16],
- *risk assessments and work-related health* in the mining and construction industries: two expert physicians, four healthcare personnel and 20 workers have been involved [12].

Due to the broad range of potential users and target domains, ACKTUS has been developed in an agile and incremental process in which common structures of the different application domains have been identified and modeled. These modules have been applied to the application domains and evaluated, and the results have been fed into further development.

Since focus has been broadened from clinical decision support systems for medical professionals' needs, to decision support and disease management support for individuals who suffer from a medical condition, two studies are ongoing where knowledge-based applications are being developed for cooperative work between the healthcare professional and their client. The two research projects are focussing the domains of chronic obstructive pulmonary lung diseases (COPD) and incontinence respectively. Preliminary results are described in Section 2.3.5.

2.2 System Architecture

ACKTUS novelty lies in the combination of modeling knowledge alongside with modeling the interaction to be taking place with the knowledge. This means that the domain expert reflects on how the knowledge will appear to the user and models the knowledge accordingly to achieve the intended goals of using the application. Likewise, the domain expert takes a stand in the essentials of the knowledge to be medicated to the user, and design the interaction accordingly. Thus, the domain professionals are modeling with the target user group in mind, and can test their prototype applications on fictive use cases. This is reflected in the modules of the ACKTUS platform (Figure 1). The ACKTUS architecture is composed by the following three layers:

Data layer: The primary aim of this layer is to structure and store the information modeled by the domain experts. This layer will also keep the information which is collected from the interaction layer and inferred from the intelligence layer in the end-user application. Moreover, this layer also keeps the structure of the graphical user interface of the end-user application as designed by the domain expert. The data layer is managed using semantic data repositories. This layer has been implemented using SESAME repositories[1], consequently, the information is captured in terms of RDF data (the Resource Description Framework (RDF)[2]) and OWL ontologies (the Web Ontology Language (OWL)[3]). The primary semantic model which is kept in this layer is *the ACKTUS semantic model* which is managed as an OWL ontology (i.e., core ontology). This semantic model plays a key role for managing issues of *data interoperability* between the different components of an architecture including additional applications.

In addition to the information modeled by the domain experts, there is functionality, which stores information about end-users' behavior when using the targeted end-user application. Events are stored in an actor repository, and in a repository for behavior patterns.

Intelligence layer: The main aim of this layer is to support *decision-making*. The semantics underpinning the reasoning applied in ACKTUS is based on an outline of a context-based argumentation framework incorporating values [13]. The Argumentation Interchange Format (AIF) [4], developed for facilitating argument exchange and visualization of argumentation over the World Wide Web is integrated into the core ontology. AIF was extended with concepts and values representing uncertain information, and is the base for extracting rules and arguments in decision-making tasks. For this purpose two basic inference engines have been developed, which follow what the domain professional

[1]http://www.openrdf.org/
[2]http://www.w3.org/RDF/
[3]http://www.w3.org/2001/sw/wiki/OWL

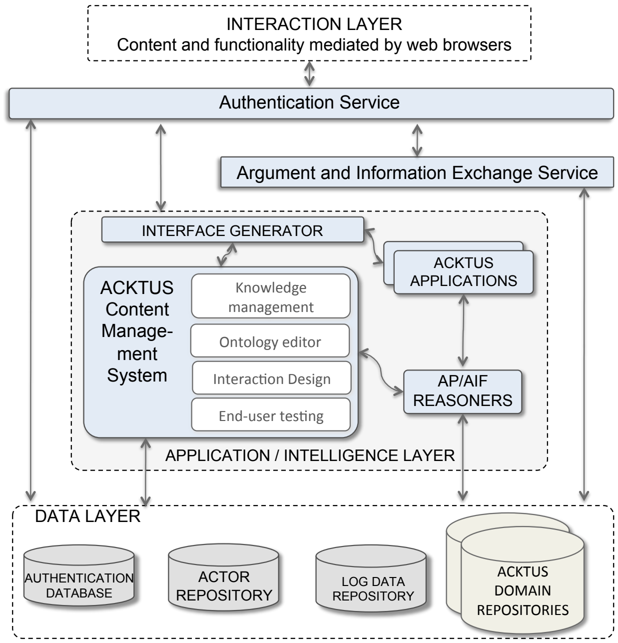

Figure 1: ACKTUS modules

has modeled. The *AP-reasoner* executes the assessment protocols, which is used in the modeling tasks for testing flows of interaction and support for reasoning (Example B in Figure 3). The *AIF-reasoner* executes a set of extracted rules, selected based on reasoning contexts, as defined by the modeling domain expert (Example A in Figure 3). This is used for testing the knowledge content in patient cases. These two engines are also used in different end-user applications (Example C in Figure 3).

Interaction layer: The main purposes of this layer are to allow the user model the content and interaction with the targeted application. The user interacts with a web application built on top of the RDF repositories using Java. The web application can display knowledge in several different languages and has interactive visualizations of the knowledge structures by using Graphviz and Ajax techniques. In ACKTUS, the visualization of the knowledge structure is created by using Graphviz[4] package that produces SVG (Scalable Vector Graphics) embedded in XHTML (eXtansible HyperText Markup Language). In addition to (X)HTML the web application can also output JSON and XML to support updates to the user interface done using the jQuery javascript library. Examples of graphical user interfaces are shown in Figures 2 and 3.

In addition to these layers web services are provided for allowing third party applications utilizing ACKTUS. The main services are the *authentication service*, and the *argument and information exchange service*. In the following section the semantic model of ACKTUS will be further described.

[4]http://www.graphviz.org/

2.2.1 Ontologies

The ACKTUS core ontology consists of an *actor and activity (AA) ontology* and a *reasoning and knowledge modeling (RKM) ontology*.

In addition to these, an *Actor repository* is used for storing the information specific for a user in an ontology based on *events*, to which sets of information are associated. The events and information are extracted and put into a semantic context using the ACKTUS core ontologies when user models are built for reasoning and decision making.

The initial version of the ACKTUS core ontology was developed using Protege[5] [18]. ACKTUS includes an *ontology editor* that allows the domain professional to model the class hierarchy of domain-related items in the ontology, and by this contributing to the structuring of a particular knowledge domain.

The AA ontology serves as the information model of the user. Our goal is to provide methods for achieving *holistic* user modeling in smart environments. In therapeutic terms, *holistic* means to build an interpretation of a client's situation, which covers a broad range of aspects related to physical, cognitive, psychological, social factors, abilities and limitations, situated in an environment. For achieving an efficient solution, we approach the task by using the broad ACKTUS core ontology as a reference ontology and vocabulary for information about the user and a knowledge domain, while allowing the systems and system agents to extract the information, which is relevant to a situation based on what topic is in focus in a certain situation. Similarly, the different ambient systems utilize subsets of the core ontology, which are expanded in the different applications to support the more focussed purposes of the applications. As a consequence, a sub-set of the user model is instantiated in each situation, which is comprehensive and sufficient for the situation and purpose for which it is used.

The ACKTUS *actor and activity (AA) ontology* was created based on models of human occupation (e.g., [9, 24]), the International Classification of Disability, Functioning and Health (ICF) provided by the World Health Organization[6], and other medical terminologies [18]. The AA ontology forms the semantic model of the user, the user's activities and of the user's environment. The ontology functions as a generic core ontology for health-related domains, and is expanded with more specific information for each knowledge domain following the scope and necessary granularity of a domain.

The user of the system is represented through the AA ontology as a human who acts as a user, apart from his or her roles in e.g. a work or other social environment. As a human actor, the user has motives, interests, roles, habits, skills and knowledge in domains. Furthermore, the human has a body with functions and processes and performs activities in an environment. It should be noted, however, that we make a distinction between e.g., the user's actual performance of an activity or cognitive function, and the collected *information about* the performance of an activity or cognitive function. The information is represented as instances of information-nodes (i-nodes). This distinction enables the treatment of conflicting or ambiguous information obtained from different sources as *defeasible* information, i.e., information which can

[5]http://protege.stanford.edu/
[6]http://www.who.int/classifications/icf/en/

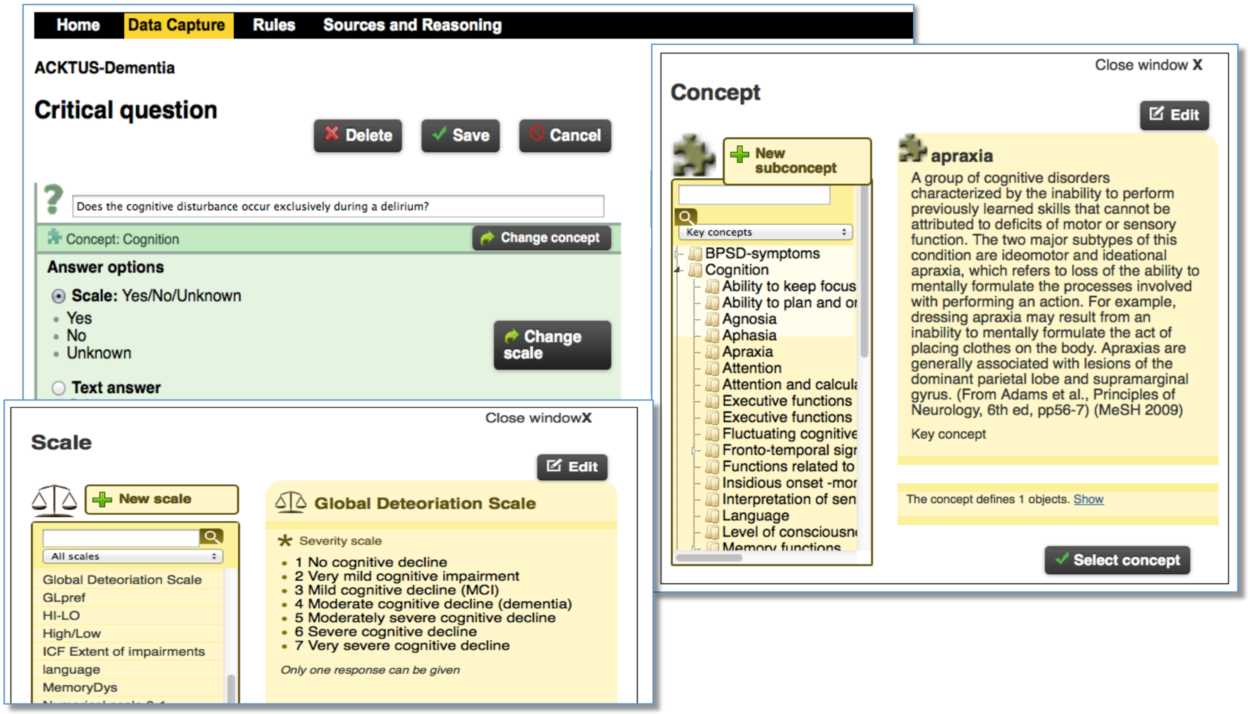

Figure 2: Editors for data capture: critical questions, scales and concepts.

be overruled, or defeated when new information is obtained. Activities are represented by the *Activities and Participation* class, following the ICF categorization as basic structure.

The RKM ontology is based on *Argument Interchange Format* (AIF) [4], expanded with nodes capturing concepts and e.g., *possibilistic* values. The information stored in the AIF-based RDF-structures is extracted into different logic languages depending on the topic and field of reasoning through an *argument and information exchange service* (Figure 1). In the exchange of information between systems, the *concept system* serves as terminology for the knowledge and reasoning nodes structured by the RKM ontology. These classes contain the three key nodes *assessment-protocol*, *i-node* and *s-node*, which are shared between the ACKTUS knowledge bases and the applications utilizing services of the ACKTUS architecture, *e.g*, the dementia diagnosis and management support system DMSS [32], the ALI system [7], Safe Step [14] and the "smart" Kitchen As-A-Pal [16].

These ontologies play a core role as a common semantic model (i.e., vocabulary) for the software agents and human actors participating in dialogues. To have a valid vocabulary in terms of ontologies helps to manage issues of *data interoperability* between the different components of ACKTUS applications.

2.3 Functionality and Interaction Design

ACKTUS provides the following key functionalities:

I) editors for developing tools and structures for data capture tasks,
II) editors for developing tools and structures for the provision of information and instructions,
III) editors for developing knowledge and reasoning content and structures, and
IV) testing functionality, partly in end user interfaces.

The editors aid the representation of semantically rich factual and procedural knowledge, which will be described in the following sections.

2.3.1 *Modeling and Maintenance of Factual Knowledge*

ACKTUS provides tools for creating, editing and updating the knowledge of a domain. Knowledge expressed in clinical practice guidelines and other evidence-based medical knowledge sources is modeled by the domain professional, in addition to other kinds of knowledge such as rules-of-thumb and best practice knowledge. There is a preference order built into the underlying ontology between knowledge sources, which can be overridden by end user's own preferences at the point of e.g., reasoning about a diagnosis.

Key classes of the ACKTUS ontology that support data capture and reasoning are the *activity-protocol*, *scale*, *concept-system-node*, and *argumentation-node*. The domain professional uses the activity protocol class for composing structured information templates for data collection (Figure 2). The purpose is to follow closely the expressions in medical literature. Therefore, the concept-system nodes are modeled to provide the conceptual knowledge with terms and definitions of phenomenon to assess. Each activity protocol becomes associated to a concept at suitable level of specificity. The concepts, their terms and definitions are retrieved from international medical terminologies when available. The domain professional can use the ontology editor for creating more specific concepts useful in their domain, organize concepts as a terminology model and translate terms to different languages.

The activity-protocols have typically one or more scales associated to them, functioning as structured alternatives for valuing the presence and characteristics of phenomenon. The scales are also created by the domain professional, typ-

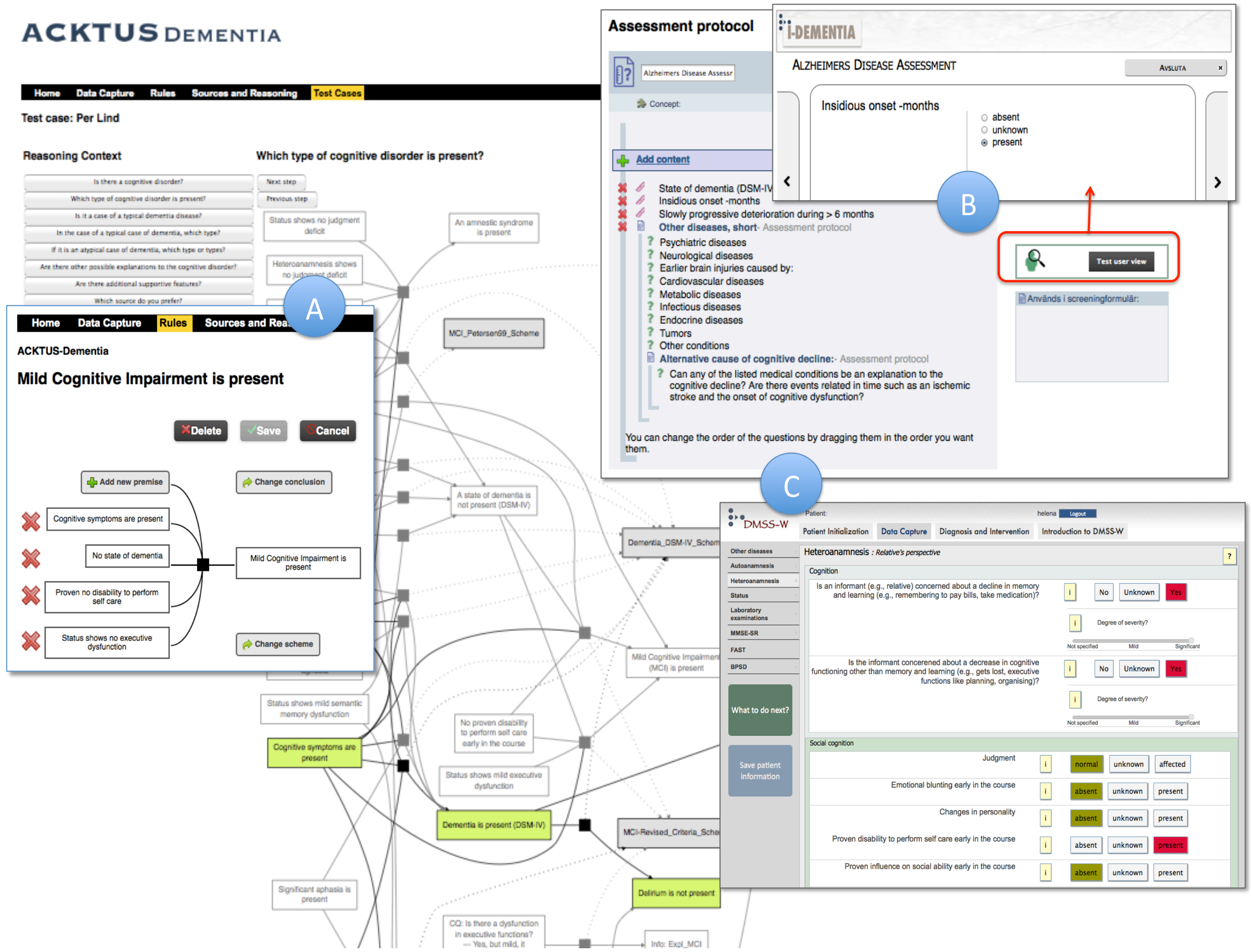

Figure 3: Three examples from the dementia domain of how the domain expert can evaluate the results: (A) an overview of potential inferences and their grounds based on the rules and their schemes can be tested in a patient case. The result is visualized as an interactive graph; (B) the step-by-step execution of nested assessment protocols is shown in Example B; and (C) the content, inference flows and conclusions can be tested in the graphical user interface of the end user application. Here the decision-support system for dementia diagnosis and management DMSS-W is shown, which builds on the ACKTUS-Dementia repository.

ically based on knowledge sources. Some scales contain a set of ordered values that mirror the uncertainty expressed in the underlying medical literature, e.g., *possible, probable, unlikely*.

2.3.2 *Modeling and Maintenance of Procedural Knowledge*

The procedural statement (s-node) editor (called "rule editor" in the program, Figure 3) allows the domain expert to define patterns of reasoning, which are used by the system agents to create *formal rules* and *arguments*. From observations or data collection tasks in a particular case, new knowledge can be derived when combined with the generic domain knowledge represented as s-nodes, such as *conclusions* about diagnoses, *recommendations* and advices, and suggestions, or the initiation, of *activities*. Each premise or conclusion is given a label in natural language, which is used in dialogues and for generating explanations for reasoning and decisions made.

Each s-node is associated to a *scheme*, which represents a semi-formal pattern of reasoning typically based on a clinical diagnostic criteria or similar. The default scheme is the argumentation scheme *argument from expert opinion* defined by Walton [31], representing the domain professional currently modeling the knowledge. In domains where the evidence-based knowledge is weak, this scheme is typically used.

For providing support to the potential end user in reasoning about e.g., diagnosis, the domain professional can use *assessment protocols* (Figure 3) and *reasoning contexts*. The assessment protocols are ordered collections of data capture templates and other assessment protocols, composed as protocols for assessment focussing different domains at different levels of specificity.

While the assessment protocols aid the end user in basic data capture activities, the reasoning contexts are designed to aid the end user in higher-level reasoning and decision-making. They consist of unordered sets of schemes, composed for the purpose to provide the user the available sources of knowledge in reasoning about a topic (Figure 3). The reasoning contexts are defined and triggered by a critical question, a type of data collection template. The primary outcome of applying a reasoning context is the answer to the question. A procedural relationship between reasoning contexts can be defined, as a proposal of how the reasoning process should be accomplished.

2.3.3 Adaptability and Personalization

The design of the support for reasoning is based on the different methods for clinical reasoning observed among medical personnel (e.g., [22]). Depending on level of expertise and situation the professional applies different strategies. Therefore, we distinguish between lower-level data capture activities, which are highly structured for the lesser skilled, compared to higher-level reasoning, which is supported using loosely coupled reasoning contexts without internal order.

The domain professional can tailor the flow of execution of assessment protocols based on user characteristics (e.g., gender, work tasks, profession, time spent in different hazardous work environment, end user's interest, level of expertise in e.g. dementia diagnosis, etc.). This is done using the rule editor. The execution of the rule base when assessing e.g., diagnoses, can be tailored based on the end user's preferences among diagnostic criteria.

2.3.4 Methodology for Validation of Content

The design of the ACKTUS ontology and associated editors is aimed at achieving transparency in each phase of the knowledge modeling. For evaluating the content, the domain professionals can review the underlying medical documents, compare the content to the interpretations made in the form of schemes. Ambiguities can be identified and discussed with, e.g., authors of the underlying medical guidelines [17]. A selection can be made among different possible interpretations, and verified among domain experts. While the *schemes* represent semi-formal interpretations of the possible decisions that can be made based on the source and available information about a patient, the *s-nodes* (used for extracting rules) are designed to implement the schemes in actual patient cases based on information obtained in e.g., observations or clinical interviews.

The behavior of the composed s-nodes can be tested by the domain experts using patient cases, which can also be composed by the domain professional for the purpose (Example A in Figure 3). The rules implementing the diagnostic reasoning can be tested using the patient case, providing the user an overview of the execution of the rule base in the form of a graph, visualized following the composed reasoning contexts. The graph shows the findings collected using the data collection templates, the executed rules, and their schemes. In this way the domain professional can evaluate the reasons (arguments) for a conclusion proposed by the system.

The results can also be tested in two differently designed graphical end-user interfaces (GUI). One is form-based, visualizing the data collection templates as composed and categorized into assessment protocols (Example C in Figure 3). In this GUI the application functions as a checklist for assessment, with rule execution functionality available for evaluating the findings. The other alternative is to test the results using a GUI, designed for persons who may be less familiar with computer use. The interaction design is simplified, showing the user one data capture template at the time, allowing for testing information and assessment flows tailored to a user case (Example B in Figure 3).

2.3.5 Evaluation Studies

Different aspects have been in focus for qualitative studies with domain experts participating in the modeling of knowledge and interaction. Different types of professionals participated in a study from four different knowledge domains (occupational health focussing two domains, dementia and rehabilitation of older adults) [19]. The results showed that all within two sessions were able to compose a knowledge-based assessment instrument to be used by colleagues in daily practice.

Domain experts modeled the knowledge regarding dementia diagnosis and the results were verified by authors of one of the guidelines in focus [17]. It was observed that the physicians were able to identify ambiguities in the source documents, and they modeled the knowledge in a more strict way compared to when they relied on a knowledge engineer to implement what they formulate in an informal way.

A pilot study was made of a period of distributed collaborative knowledge modeling with the goal to customize the clinical decision-support system for dementia diagnosis to local practice [20]. The customization was done by local medical professionals and evaluated with domain experts. As a result, the local medical professionals introduced a short version for novices, while educating the professionals in dementia management before implementing the full version. The full version is currently being implemented in a larger community of primary care physicians, who need support for improving diagnosis and management of dementia patients.

ACKTUS was used for transforming informal knowledge obtained in a series of participatory design sessions with two groups of older adults and physiotherapists, into formal knowledge implemented in a mobile application for older adults [14]. A feasibility study will be conducted within the near future of the resulting evidence-based intervention for preventing falls.

An ongoing study is investigating how cooperative care can be accomplished, where supportive applications are being developed using ACKTUS for individuals who suffer from chronic obstructive pulmonary disease (COPD) or incontinence. There resulting applications are aimed to support both the individuals and their healthcare professionals. The modeling domain experts are physiotherapists and physicians respectively, who are not familiar with neither knowledge engineering or interaction design. Preliminary results show that guidance is needed in the initial phase of translating informal domain expertise and ideas about design into formal representations using the ACKTUS modules. The naming of different objects in the user interface and guidance how these can be used for composing the content and interaction flows can be improved.

3. RELATED WORK

There is a number of different modeling languages developed for the purpose to function as instruments in the translation of clinical practice guidelines (CPGs) into computer-interpretable versions (CIGs) [23]. A few examples are Asbru [25, 26, 5], PROforma [28, 27] and GLIF3 [2]. ACKTUS shares the aim with these, to provide an instrument for translating clinical practice guidelines into a computer-interpretable format for developing clinical decision support systems. However, ACKTUS differs from these initiatives in that ACKTUS allows also the representation of best practice, or "rules of thumb", which are knowledge not yet validated in evidence-based medicine. Consequently, the transparency is essential, and the valuation of the sources of knowledge, following an ontology of reliability. Besides an ontology of reliability, this is accomplished using *argumentation schemes*, which further describes the source.

ACKTUS also differs from these in that ACKTUS is aiming at allowing healthcare professionals, who are not experienced in knowledge engineering, to model knowledge and to construct their envisioned supportive applications. The platform is designed to be used by medical or health professionals who are not necessarily experienced in knowledge engineering or interaction design.

Another difference from the guideline representation languages, is that the targeted users of applications developed using ACKTUS may be the patient, or client who may be suffering from a medical condition, or at risk for injuries, and not necessarily a medical professional. Since ACKTUS also allows the domain expert model knowledge in an interaction design context, the expert can aim for optimal presentation of information seemed as crucial for the patient/client to receive. Aspects regarding motivational factors become essential, e.g., for promoting a change of behavior, and methods for personalization.

ACKTUS shares similarities with PROforma in that both use arguments, which may be defeasible [28]. A difference is that PROforma restricts the defeasible arguments to be assigned same confidence level, and the number of arguments in favor and against a statement is counted and compared. In ACKTUS different levels of confidence can be assigned an argument, which was considered necessary for managing the uncertainty in the dementia domain.

At a superficial level, ACKTUS can be seen as a content management system (CMS). However, the ontologies underlying the platform, and the potentials in using inferences to generate support and conclusions, advance ACKTUS beyond traditional CMSs.

4. CONCLUSIONS AND FUTURE WORK

This paper introduces ACKTUS, which is a web-based platform for developing knowledge-based applications. The platform is designed to be used by professionals such as medical domain experts who are not necessarily experienced in knowledge engineering or interaction design. ACKTUS novelty lies in the combination of modeling knowledge alongside with modeling the interaction to be taking place with the knowledge. Thus, the domain professionals are modeling with the target user group in mind, and can test their prototype applications on fictive use cases. Moreover, the results can immediately be tested in an end-user view, which enable rapid prototyping and cooperative design, involving also citizens who are potential end users. Researchers in different medical and health domains are able to develop new evidence-based interventions and conduct studies with clients.

The end user may be a colleague, a group of patients or other persons. The aim is providing personalized support to users such as non-expert clinicians at the point of care, or construction and mining workers in monitoring and preventing work related injuries. The potential end-users of the knowledge-based support applications developed so far range from different kinds of health professionals, mining and construction workers, older persons in their homes, adolescences, individuals with cognitive or mental deficiencies.

Three of the research projects are now investigating how to integrate information from wearable sensors or sensors in the environment into support applications developed using ACKTUS. As a consequence, the information and argument interchange services in ACKTUS will be further developed.

Future work will aim to improve the interaction design of ACKTUS based on the results from the ongoing studies, and focus on scalability and interoperability. One goal is to develop methods for mapping content to other platforms for interventions, e.g., national platforms for service provision in healthcare. ACKTUS is currently functioning as a research and innovation infrastructure for the research groups, which are using the platform for developing prototypes for evaluating interventions with end users. In this process, ACKTUS is being used as an instrument for disseminating research results from evidence-based medical studies to clinical practice or individuals' daily living. Considering the broad variety of application domains so far, it is expected that ACKTUS can function as the bridge between research and clinical practice/everyday living of individuals with health conditions also in additional medical and health knowledge domains in the future.

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6. REFERENCES

[1] F. Baum, C. MacDougall, and D. Smith. Participatory action research. *Journal of Epidemiology and Community Health*, 60:854–857, 2006.

[2] A. A. Boxwala, M. Peleg, S. Tu, O. Ogunyemi, Q. T. Zeng, D. Wang, V. L. Patel, R. A. Greenes, and E. H. Shortliffe. Glif3: a representation format for sharable computer-interpretable clinical practice guidelines. *Journal of Biomedical Informatics*, 37(3):147 – 161, 2004.

[3] M. Cabana, C. Rand, N. Powe, A. Wu, M. Wilson, P. Abboud, and H. Rubin. Why don't physicians follow clinical practice guidelines? a framework for improvement. *JAMA*, 282:1458–1467, 1999.

[4] C. I. Chesñevar, J. McGinnis, S. Modgil, I. Rahwan, C. Reed, G. R. Simari, M. South, G. Vreeswijk, and S. Willmott. Towards an argument interchange format. *Knowledge Eng. Review*, 21(4):293–316, 2006.

[5] C. Eccher, A. Ferro, A. Seyfang, M. Rospocher, and S. Miksch. Modeling clinical protocols using semantic mediawiki: The case of the oncocure project. In *K4HelP 2008*, volume 5626 of *LNAI*, pages 42–54, 2009.

[6] B. Fogg. A behavior model for persuasive design. In *Proceedings of the 4th International Conference on Persuasive Technology*, Persuasive '09, pages 40:1–40:7, New York, NY, USA, 2009. ACM.

[7] E. Guerrero, H. Lindgren, and J. C. Nieves. ALI, an Assisted Living System Based on a Human-Centric

Argument-Based Decision Making Framework. In *13th Workshop on Computational Models of Natural Arguments (CMNA 2013)*, pages 46–51, 2013.

[8] R. Kadouche, M. Mokhtari, S. Giroux, and B. Abdulrazak. 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, pages 411–415, 2008.

[9] V. Kaptelinin. Computer-mediated activity: Functional organs in social and developmental contexts. In B. Nardi, editor, *Context and Consciousness. Activity Theory and Human Computer Interaction*, pages 45–68. MIT Press, 1996.

[10] A. Kobsa. Generic user modeling systems. *User Modeling and User-Adapted Interaction*, 11(1-2):49–63, Mar. 2001.

[11] H. Lindgren. Towards personalized decision support in the dementia domain based on clinical practice guidelines. *User Modeling and User-Adapted Interaction*, 21(4-5):377–406, 2011.

[12] H. Lindgren, L. Burström, and B. Järvholm. Developing ambient support technology for risk management in the mining industry. In C. Ramos, P. Novais, C. E. Nihan, and J. M. Corchado Rodriguez, editors, *Ambient Intelligence - Software and Applications*, volume 291 of *Advances in Intelligent Systems and Computing*, pages 161–169. Springer International Publishing, 2014.

[13] H. Lindgren and P. Eklund. Differential diagnosis of dementia in an argumentation framework. *Journal of Intelligent and Fuzzy Systems*, 17(4):387–394, 2006.

[14] H. Lindgren, L. Lundin-Olsson, P. Pohl, and M. Sandlund. End users transforming experiences into formal information and process models for personalised health interventions. *Studies In Health Technology And Informatics*, 205:378–82, 2014.

[15] H. Lindgren and I. Nilsson. Designing systems for health promotion and autonomy in older adults. In T. Gross, J. Gulliksen, P. Kotzé, L. Oestreicher, P. A. Palanque, R. O. Prates, and M. Winckler, editors, *INTERACT (2)*, volume 5727 of *Lecture Notes in Computer Science*, pages 700–703. Springer, 2009.

[16] H. Lindgren, D. Surie, and I. Nilsson. Agent-supported assessment for adaptive and personalized ambient assisted living. In J. M. Corchado, J. Pérez Bajo, K. Hallenborg, P. Golinska, and R. Corchuelo, editors, *Trends in Practical Applications of Agents and Multiagent Systems*, volume 90 of *Advances in Intelligent and Soft Computing*, pages 25–32. Springer Berlin Heidelberg, 2011.

[17] H. Lindgren and P. Winnberg. Evaluation of a semantic web application for collaborative knowledge building in the dementia domain. In Szomszor and Kostkova [29], pages 62–69.

[18] H. Lindgren and P. Winnberg. A model for interaction design of personalised knowledge systems in the health domain. In Szomszor and Kostkova [29], pages 235–242.

[19] H. Lindgren, P. J. Winnberg, and P. Winnberg. Domain experts tailoring interaction to users - an evaluation study. In P. Campos, T. C. N. Graham, J. A. Jorge, N. J. Nunes, P. A. Palanque, and M. Winckler, editors, *INTERACT (3)*, volume 6948 of *Lecture Notes in Computer Science*, pages 644–661. Springer, 2011.

[20] H. Lindgren, P. J. Winnberg, and C. Yan. Collaborative development of knowledge-based support systems: A case study. *Studies In Health Technology And Informatics*, 180:1111–1113, 2012.

[21] H. Oinas-Kukkonen. Behavior change support systems: A research model and agenda. In *Proceedings of the 5th International Conference on Persuasive Technology*, PERSUASIVE'10, pages 4–14, Berlin, Heidelberg, 2010. Springer-Verlag.

[22] V. Patel, D. Kaufman, and J. Arocha. Emerging paradigms of cognition in medical decision-making. *Journal of Biomedical Informatics*, 35:52–75, 2002.

[23] M. Peleg. Computer-interpretable clinical guidelines: A methodological review. *Journal of Biomedical Informatics*, 46(4):744 – 763, 2013.

[24] R. M. Ryan and E. L. Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1):68–78, 2000.

[25] A. Seyfang, S. Miksch, M. Marcos, J. Wittenberg, C. Polo-Conde, and K. Rosenbrand. Bridging the gap between informal and formal guideline representations. In *Proceedings of the 2006 conference on ECAI 2006: 17th European Conference on Artificial Intelligence August 29 – September 1, 2006, Riva del Garda, Italy*, pages 447–451, 2006.

[26] E. Shalom. Can physicians structure clinical guidelines? experiments with a mark-up-process methodology. In *K4HelP 2008*, volume 5626 of *LNAI*, pages 67–80, 2009.

[27] D. Sutton, P. Taylor, and K. Earle. Evaluation of proforma as a language for implementing medical guidelines in a practical context. *BMC Medical Informatics and Decision Making*, 6(1):20, 2006.

[28] D. R. Sutton and J. Fox. The syntax and semantics of the proforma guideline modeling language. *Journal of the American Medical Informatics Association*, 10(5):433 – 443, 2003.

[29] M. Szomszor and P. Kostkova, editors. *Electronic Healthcare - Third International Conference, eHealth 2010, Casablanca, Morocco, December 13-15, 2010, Revised Selected Papers*, volume 69 of *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*. Springer, 2012.

[30] J. van Bemmel and M. Musen. *Handbook of Medical Informatics*. Springer Verlag, 1999.

[31] D. Walton. *Argumentation Schemes for Presumptive Reasoning*. Erlbaum, Mahwah, NJ., 1996.

[32] C. Yan and H. Lindgren. Hypothesis-Driven Agent Dialogues for Dementia Assessment. In *VIII Workshop on Agents Applied in Health Care (A2HC)*, pages 13–24, 2013.