

# Evaluation of a Semantic Web Application for Collaborative Knowledge Building in the Dementia Domain

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**Abstract.** This paper presents the results from a qualitative evaluation study of the semantic web application ACKTUS-dementia, developed for the purpose of supporting a distributed collaborative knowledge engineering process. The main purpose of the study was to investigate whether the functionalities used for the purpose are intuitive and to what extent expert physicians are able to use the system for the purpose intended. The experts were observed when executing tasks and interviews were conducted to investigate issues and attitudes concerning integrating contextual knowledge to enrich the knowledge in the application. Results indicate that the system fulfils its purpose and is useful for capturing sources of possible misinterpretations, possible alternative interpretations and ambiguities in the domain knowledge. There was also an interest expressed to extend the system to include contextual knowledge for the international collegiums to share as a continuing medical education apart from supporting patient-centric assessments.

**Keywords:** Evaluation, clinical practice guidelines, clinical decision support system, personalization, knowledge modeling, semantic web, dementia.

## 1 Introduction

Transforming medical knowledge residing in individual experts and in domain knowledge sources to formal structures to be integrated in intelligent support systems is a challenging task in the development of clinical decision support systems (CDSS) [1]. There is a trade-off between designing an interaction environment in which the clinician can easily provide with 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 [2, 3, 4, 5]. The problem is similar when experience-based knowledge is to be communicated in a web-based forum for e.g. medical professionals. ACKTUS is a collaborative knowledge-modeling framework that aims at simplifying the entering of knowledge without losing significant characteristics in the

knowledge, and also at providing means to design the interactive reasoning. The purpose is to create semantic web based applications that provide personalized support to users such as non-expert clinicians at the point of care or to construction and mining workers in monitoring and preventing work related injuries. Another purpose is to use semantic web techniques for creating professional networks where the development and sharing of knowledge can be accomplished in a daily work environment as a natural part of daily work tasks. This poses high demands on interaction design and ecological validity, requiring an activity-centered and socio-technical approach to development and integration [6, 7]. ACKTUS is applied in the dementia domain and currently expert physicians in Sweden and Japan are involved for modeling the knowledge. This paper presents an evaluation study of ACKTUS-dementia conducted within a Swedish research community, highly influential on the international development of the evidence-based knowledge in the domain. Focus was on qualitative aspects of the process of interpreting and formalizing guidelines, and the views and attitudes among the experts in the research community on the integration of research results and contextual knowledge using semantic web techniques for the benefits of clinical practice. The purpose was to investigate whether the process of acquisition, validation and updating of knowledge can be facilitated using ACKTUS, with a focus on two clinical guidelines. Also issues were investigated regarding what type of knowledge produced by the research community would be suitable for integration in a CDSS for the purpose of disseminating the results to the clinical encounter with a patient with a suspected dementia disease.

The paper is organized as follows. In the next section ACKTUS-dementia is described, followed by a section presenting the evaluation study. Finally, a summary is provided and conclusions are drawn, providing implications for future work.

## 2 ACKTUS-Dementia

ACKTUS-dementia is built using the knowledge and interaction-modeling environment ACKTUS. Functionalities are included that support the development of the knowledge as an international distributed collaborative work, using the semantic web. ACKTUS is based on a web service architecture that integrates specially designed ontologies and argument (i.e., rule) repositories. These are extended with domain specific content in application projects such as ACKTUS-dementia. The ontologies contain features and relationships identified in the activity and user model described in [8], and the components of reasoning are based on a draft of a context-based argumentation framework [9, 10], which is implemented using the argument interchange format for reusability through the world wide web [11]. The argumentation framework contains *argument schemes* (i.e., patterns of reasoning [10, 11]) for specifying contexts of reasoning and for handling preferences that can be used in the reasoning about different aspects of diagnosis and care. Such aspects can relate to qualities of knowledge sources and screening instruments, local priorities and individual preferences about which tools to use. The schemes are also used for translating clinical guidelines into a semi-formal structure that can be visualized in the reasoning about patient cases or in the verification of rules in the system.

A CDSS for dementia (Dementia Management and Support System - DMSS) was used as source for the creation of the ontology, schemes, arguments, scales and items for ACKTUS-dementia [6]. The rules integrated in DMSS were translated into arguments and the items with associated value scales for reliability in the assessment of presence and severity were modeled as base for the creation of arguments.

ACKTUS-dementia serves the following purposes:

- 1) structuring the interpretations of clinical guidelines and informal rules of thumb as schemes, representing an intermediate level of formalization in the knowledge assessment process,
- 2) tool for formulating and formalizing rules based on knowledge in clinical practice and consensus guidelines,
- 3) providing the experts involved in the process a tool for direct verification of the rules formulated based on an interpretation of a clinical guideline,
- 4) integrating meta-knowledge such as preferences, partly for allowing a more pragmatic and personalized approach to decision support in clinical practice,
- 5) allowing domain experts to contribute to interaction design by identifying what knowledge needs to be assessed by the user in a patient case and in dialogue with the future decision support system, e.g. due to vague definitions in the sources,
- 6) provide domain experts the possibility to define contexts of interpretation of patient information,
- 7) allowing domain experts to contribute to interaction design by modeling assessment protocols corresponding to a model of the assessment activity,
- 8) enabling an international distributed knowledge engineering work using the semantic web.

In the evaluation study presented in this paper the purposes 1, 2, 3, 5 and 8 were focused in the evaluation sessions, and interviews and the views and opinions about purpose 4 were evaluated in interviews. 6 and 7 is subjected to future evaluation studies targeting the expert physicians' modeling of the end user interaction with the integrated knowledge in patient cases.

### 3 Methods and Material

The clinical practice guideline DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, fourth edition) [12] was included in this case study for the purpose of validating existing interpretations and rules in DMSS that were based on this guideline and imported to ACKTUS-dementia. In order to examine the process of integrating a new guideline, the clinical practice guideline for mild cognitive impairment MCI-R [13] was also included in this study, which had before the study not been integrated into DMSS or ACKTUS-dementia.

The study design was qualitative, with observations of physicians completing the assigned tasks, supplemented with interviews. Six expert physicians participated, four men and two women, who all were active researchers and clinicians in the dementia domain, partly as authors of clinical consensus guidelines.

Two expert physicians were first assigned the collaborative task of controlling and revising the existing schemes and rules that were based on DSM-IV and imported

from DMSS. This was done partly for the purpose of familiarizing them to the structure of the system. Next task was to integrate a new guideline (MCI-R), first as a scheme and then as rules that instantiate the scheme. Finally, the physicians applied the schemes and rules on predefined, fictive patient cases.

At a later occasion, one of the authors of the guideline validated the scheme-interpretation of the guideline MCI-R and the associated rules. Three additional expert physicians contributed to the process by verifying the particular guideline integration and by participating in interviews. All participating physicians were interviewed, using semi-structured questions. For elaborating on examples of knowledge that could be included in a CDSS, recent results were used from research in the domain.

## 4 Results

The results are divided into results related to the formalization and validation of the knowledge extracted from the two guidelines, and results from interviews about the relevance and qualities of research results that can be referred to as meta-knowledge.

### 4.1 Formalization and Validation of Knowledge from Clinical Guidelines

The two physicians were able to identify ambiguities in the clinical practice guidelines in the process of interpreting one into the semiformal structure and evaluating the existing interpretations (Figure 1a, 1b). Alternative ways to interpret the guidelines were identified, and discussions lead to a consensus on which was perceived as the most correct one. The interpretation of the MCI-R guideline was later validated by additional experts, of which one was a co-author of the guideline. It was confirmed that the interpretation was fulfilling the intentions with the diagnostic criteria as expressed in the guideline and as expressed during the development of the guideline.

The second task in the integration of a clinical guideline using ACKTUS is to create rules and associate these to schemes, and match clinical findings, or *evidence*, with preconditions and conclusions in the schemes (Figure 1b, 1c). The experts make in this phase decisions about what set of findings is a sufficient precondition to a conclusion. The experts were observed to formulate stronger requirements on preconditions than the guideline expresses in some cases, and in other cases the instantiation of a precondition was weaker or not possible to include as an unambiguous part of a rule. The latter was seen in particular where guidelines express vagueness, or that the influence of a finding needs to be determined by the clinician in a larger perspective than provided by the system. One example is the precondition for Alzheimer's disease as formulated in DSM-IV [12]:

*The cognitive deficits are not due to any other general medical condition.*

The physicians identified such premises to be handled using *critical questions* in the interaction design of the CDSS in several of the schemes based on DSM-IV, due to its circular definitions of disorders. They found this way of handling this complexity purposeful, and satisfactory considering that the task to exclude all other medical conditions in a rigorous way is in daily clinical practice under time and resource constraints, very difficult.

The screenshot displays the ACKTUS DEMENTIA web application interface. At the top, it shows the logo and the user's name, Helena Lindgren. A navigation bar includes links for Home, Knowledge Sources, Schemas, Rules, Patient Cases, and Administration. The main content area is divided into several sections:

- Knowledge Sources:** A table listing various sources such as 'AD Criteria, Dubois 2007', 'Dementia, O'Brien et al. 2000', and 'DLB consensus, McKeith et al. 2005'. A search box labeled 'a' is positioned above the table.
- MCI-Revised\_Criteria\_Scheme:** A detailed view of a guideline scheme. It includes a status 'Under discussion' (labeled 'b'), a list of knowledge sources, and a section for 'Premise Descriptions' with several criteria listed. A 'Conclusion Description' states 'MCI is present according to the revised criteria'.
- Rules based on this scheme:** A section showing a flowchart of rules. Four premises (e.g., 'Proven no disability to perform self care', 'No state of dementia') lead to a central node, which then leads to the conclusion 'Mild Cognitive Impairment is present' (labeled 'c').
- Patient Test Case:** A graph showing a patient's test case for evaluation. It includes a search box, an 'Analyze' button, and a network diagram with nodes representing different symptoms and their relationships. A specific node is highlighted, representing a part of a guideline (labeled 'd').

**Fig. 1.** The functionalities focused in the evaluation study: a) knowledge sources, b) semi-formal interpretation of guidelines (i.e., knowledge sources) in the form of argumentation schemes, c) associated rules, and d) patient test cases for evaluation, here with a scheme-node in the graph opened, representing a part of a guideline.

The two physicians quickly identified rules that did not comply satisfactory with the semi-formal guidelines. They were observed to make a more strict interpretation of the clinical guidelines when they committed to an interpretation of the guideline before they verified the rules. Features such as level of granularity of concepts, temporal relations and distinction semantically between missing data and absence of phenomenon were discussed and were reasons for revision of rules.

Additional physicians evaluated at a later stage the rules that were associated with the MCI-R guideline and corresponding scheme, constructed in the initial session. The rules were found satisfactory and fulfilling the schemes.

The rules and schemes were visualized in patient test cases (Figure 1d), which the physicians found valuable for the modeling purpose. However, they were skeptical to use such graphical representations for presenting information to a primary care physician in daily practice.

## 4.2 Including Contextual Knowledge

The weaknesses of rules, inherited from the incomplete underlying domain knowledge were highlighted. In particular, the absence of validated cut-off scores for determining the existence of certain key dysfunctions may in patient cases generate less reliable results such as in the criteria for mild cognitive impairment. This can be highlighted in the system for promoting awareness about this, which was perceived particularly important when a certain set of suggested diagnostic criteria is not reliable until the cut-off scores have been determined and validated.

The knowledge that is important from a preventive perspective was also discussed as well as factors affecting the course of dementia diseases. Meta-knowledge such as the recent findings that women are subject for less costly assessment methods than men in the dementia work up, and characteristics of clinical guidelines such as sensitivity and specificity measures, were considered as knowledge that could be useful in clinical practice. Also the evidence that individuals with higher level of education are typically subjected to a later onset but also a more aggressive progression of dementia was considered as valuable knowledge to provide the physician at the point of intervention and follow up.

Certain maturity in diagnostic criteria was by two of the experts considered necessary before their inclusion in a CDSS, even if meta-knowledge about status of the knowledge also could be included. Two other experts had a more pragmatic and practical view of the current situation with changing evidence-based knowledge. They referred to the change of views on specific cut-off scores that has been seen in the dementia research domain for a long time, and perceived it more important to provide an optimal support, even in the absence of validated cut-off scores in order to improve the dementia diagnostic process in clinical daily practice. In their view this motivation also applied to the use of new guidelines.

## 5 Discussion

The time spent in the evaluation sessions was mainly on issues related to interpretation of guidelines and less on learning how the system works or on implementation of knowledge. Although the different ways of visualizing the knowledge were perceived as useful by the physicians, other issues related to interaction design and usability, such as to what extent ACKTUS is as easy to use for medical personnel working on their own, are subjects for future evaluation studies.

Also subjected to future studies is in what way the distinction between knowledge at different levels of granularity and contexts of use can be supported. For instance, a few of the experts had initially difficulties in distinguishing between what is their task in the formalization process since this was a completely new role for them. They tended to fall into the roles of clinical guideline developer, guideline validator or researcher in general and sometimes also the role of the diagnosing general practitioner, by dwelling on issues not immediately relevant to the current task of validating an existing guideline interpretation or a rule. However, this gave implications to in what way the continuation of the project will be conducted and to a re-design of the user interface, providing a view of the content tailored more to the user and to the current task.

The difficult task of assessing basic dysfunctions in a patient case and providing support for this is another obstacle since the clinical guidelines often assumes that this is already done. This is related to the non-existing cut-off scores for the basic assessments, and the physicians' need to be supported using the few existing screening tools available that are suitable for general practitioners in daily practice. Consequently, preferences on what tools to use, and the reliability of information included in the reasoning process based on the methods of data gathering should therefore be integrated. For instance, information can be included about the source and instruments that have been used in the assessment of dysfunction, in order to provide the physician means to value the results that the system generates. Augmenting knowledge with meta-knowledge that enriches the context of reasoning and qualities in the accessible knowledge would solve some disagreements that the experts had on the issue when research results are mature and reliable enough to be mediated to clinicians in clinical practice.

## 6 Conclusions

A qualitative evaluation study of ACKTUS-dementia is presented in which six expert physicians have participated and performed tasks related to the development of knowledge to be integrated in a clinical decision support system for the domain. The results indicate that ACKTUS-dementia is useful as a tool for developing a rule-based and mixed-initiative clinical decision system for dementia care for collaborative and distributed use on the semantic web. In particular, the system is useful for capturing sources of potential misinterpretations of clinical domain knowledge, possible alternative interpretations, capturing ambiguities in the domain knowledge and mediating this to the user for the purpose of increasing knowledge in the user and providing decision support in the process of knowledge acquisition in a physically distributed and collaborative setting.

ACKTUS-dementia is currently being further developed to integrate modeling functionality for the experts to contribute to the design of the user interface of a web-based version of a CDSS for dementia care. The application will function as a tool for development and updating of the integrated knowledge. This work will be done in an internationally distributed and collaborative setting involving additional expert physicians. Furthermore, ACKTUS will be developed and evaluated in projects for knowledge acquisition in the rehabilitation and nursing domains as a step towards the creation of a knowledge base and interaction design suitable also for a teamwork setting in clinical practice. In these projects the reusability of arguments between different knowledge domains will be further explored.

Improving dementia care by providing tailored advice to professionals at the point of care when assessing a possible dementia case is the major purpose of ACKTUS-dementia. ACKTUS-dementia can be seen an intelligent knowledge repository and knowledge-modeling environment facilitated by semantic web technology, with users distinguishable by their profession and access rights to contribute to the creation and modeling of the content. As such, the system has the potential to grow into hosting an international community of researchers and professionals active in clinical practice contributing to improving dementia care, yet allowing for different needs and motives for using the application with its knowledge.

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