Towards Using Argumentation Schemes and Critical Questions for Supporting Diagnostic Reasoning in the Dementia Domain

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Abstract

This paper describes the ongoing modeling of knowledge in clinical guidelines as schemes in an argumentation framework. The work is done to address the problem of synthesizing different evidence-based clinical guidelines and integrating these in a decision-support system in a way so that the system complies with clinical routines and reasoning processes, and supports hypothesis generation and evaluation in daily practice. Preferences orders on guidelines and modalities are integrated in order to enrich the reasoning process in the diagnosis of atypical dementia cases.

1 Introduction

In clinical practice when investigating a suspected dementia disease, a range of additional medical conditions needs to be considered in a differentiation process. In addition, the assessment of the existence and severity of symptoms is crucial, especially since dementia diseases are progressive, and need to be continuously monitored. In order to capture the state of the domain knowledge several guidelines need to be considered. These express the knowledge differently, sometimes with terminology that mirrors the underlying uncertainty of the domain knowledge. Since the evidence-based domain knowledge is still ambiguous and incomplete, the clinical guidelines are interpretations of this knowledge into a form that can be useful in clinical practice as recommendations. By integrating the guidelines in a decision-support system used in clinical practice, their use is expected to increase and possibly also the adherence to them. As a consequence, the quality of dementia care is expected to increase. When taking the characteristics of the decision-environment into consideration, methods that allow for representing uncertainty, granularities, severities and defeasible reasoning in a process perspective are required in order to provide aid for the physician's reasoning process and knowledge development. The following issues are fundamental:

- How synthesize different clinical guidelines and protocols representing ambiguous knowledge, formally and in presentations for the user to act upon?
- How support hypothesis generation in a situation with incomplete data?
- How enrich the reasoning process with contextual knowledge to promote development of knowledge and collaboration?

These aspects are being investigated and solutions have been implemented in the prototype system DMSS in a pragmatic way, using production rules in combination with a purposeful designed interaction, in order to overcome the limitations of the rulebase and its underlying knowledge. The work is based on a context based argumentation framework [Lindgren and Eklund, 2005], where the main purpose has been to evaluate the interaction aspects and perceived benefits of using an argumentation based system in the domain. Studies indicate that a flexible support throughout the reasoning process providing motives and guidance for the situation at hand, is more useful than optimizing a rulebase that only provides with suggestions of diagnostic solutions in cases where it is possible to provide one, based on the literature and available patient data [Lindgren, 2008]. Therefore, current work aims at integrating contextual knowledge that may capture additional motives for a chosen diagnosis and deviations from clinical guideline based suggestions provided by the system in patient cases.

We perceive the work on developing an argument interchange format (AIF) suitable for incorporating different aspects of knowledge and reasoning over the world wide web as having potential to become highly useful in international collaborative efforts in developing clinical knowledge [Chesnevar *et al*., 2006; Rahwan *et al*., 2007]. The purpose of this work is to apply AIF to the basic tasks of putting forward evidence and applying rules to generate and valuate hypotheses in the diagnostic process. In particular, we will investigate to what extent argumentation schemes and associated critical questions are applicable for representing the knowledge in the domain of differential diagnosis of dementia.

In the next section an overview of AIF and the extensions made is provided, including the use of *strengths*, or *values*. In Section 3 the application of schemes and preference orders for differential diagnostics in dementia care is described, followed by a summary and conclusive remarks.

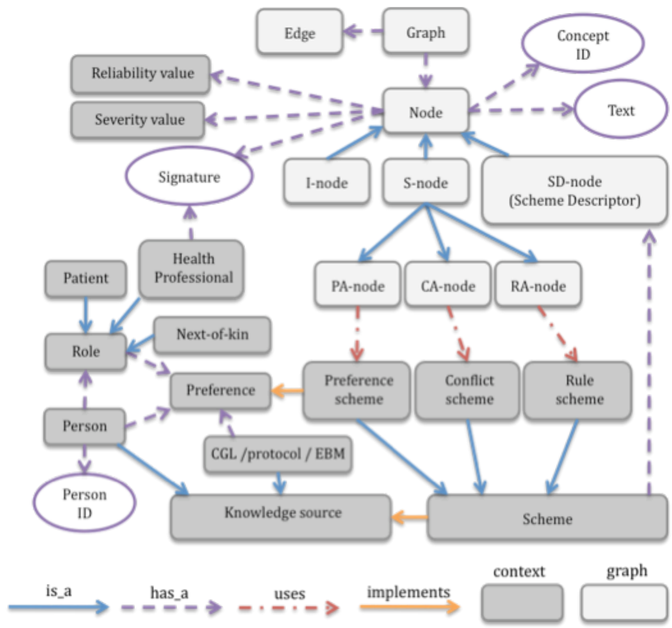

Figure 1. Extended AIF ontology.

2 Ontology of Arguments

AIF presented in [Chesnevar *et al*., 2006] is a draft for the ongoing development of a shared formalism to be used in, for instance, multi-agent systems and for sharing, editing and visualizing arguments. The model is applied to the semantic web by Rahwan and coworkers [Rahwan *et al*., 2007].

The core ontology consists of structures for *arguments and argument networks*, *communication* and *context*. We will focus on the arguments, argument networks and context in the following brief description. For a more comprehensive account, see the work of [Chesnevar *et al*., 2006].

The basic components of the ontology are *scheme nodes* (S-node), which represent rules and *information nodes* (I-node), capturing premises and conclusions in a reasoning process. The S-nodes can be of the types *rule of inference application node* (RA-node), *conflict application node* (CA-node) or *preference application node* (PA-node), and each uses a corresponding scheme. Schemes constitute an important structure in argumentation theory, which enable the application of general patterns of reasoning to arguments expressed in a local context of argumentation [Bex *et al*., 2003; Prakken *et al*., 2003; Walton, 1996]. As implied by the S-nodes' names, RA-nodes instantiate rules of inferences, CA-nodes conflicts and PA-nodes express preferences applied to either S-nodes or I-nodes. The nodes can have different attributes such as type or strengths, but they are not part of the core ontology.

The core ontology is extended by Rahwan and colleagues with a node used for capturing scheme descriptions and the critical questions associated to a scheme. We use the *scheme descriptor node* (SD-node) for this purpose (Figure 1).

Support and data supply are expressed through edges between nodes in an argument network. A restriction is put on edges between I-nodes, which are not allowed. Edges need not carry explicit semantic information since their types can be inferred by the nodes they connect. S-to-I edges can be viewed as "conclusion" edges and S-to-S edges may be used to capture "meta"-reasoning [Chesnevar *et al*., 2006; Mogdil, 2006].

A *context* in AIF is suggested to include schemes and, among other aspects, participants ID and role, the underlying formal argumentation theory, background theory and domain ontologies. In our ontology the scheme nodes implement the domain knowledge represented by relevant clinical guidelines, informal rules-of-thumb, sources of evidence, preference orders on sets of schemes and on values. In terms of [Lindgren and Eklund, 2005] and DMSS, the schemes implement the different *contexts of interpretation* of evidence including associated value orders, and also the interaction features of DMSS that handles conflicts, sometimes as critical questions to be answered, in the interaction with the user.

Research literature describes approaches to using arguments with different types of strengths and how aggregating support when arguments represent different qualities such as bi-polarity. Such properties are useful in the medical and health domains, for the purpose of handling decision making under uncertainty. PRO*forma* implements an aggregation mechanism by simply summarize the number of arguments in favor or against a proposition [Fox and Das, 2000]. A more elaborated aggregation is recently presented in [Amgoud *et al*., 2008] where also a quality measure is added to the quantitative measure. Defeasibility is in the ASPIC project indicated with a numerical weight in the range [0, 1], which is attached to each rule or fact as an indication of *degree of belief* [Chesnevar *et al*., 2006]. An alternative to numbers as weight is using modalities expressed in natural language. In the work of Nieves and coworkers this is done using possibilistic stable models [Nieves *et al*., 2007]. Their approach has been implemented in a decision-support system for organ transplantation [Nieves *et al*., 2006].

In this work each item with associated values in a patient case is treated conceptually as *evidence* and is used as premises in the reasoning process. Evidence constitutes data, symptoms, signs, observations, findings, syndromes, conditions, diseases and decisions, i.e., any piece of knowledge about a patient that contributes to the reasoning process or is a product of the reasoning. In our extended argument ontology patient-related pieces of evidence come equipped with values from two different types of scales. Some scales are defined and validated in medical literature while others are extracted from clinical guidelines. Therefore, the I-nodes in our work have been extended with a concept identifier, a reliability value and a severity value. The reliability value represents the amount of confidence in the proposition and is necessary to define for all evidence, while a severity value is applied when the context requires the information. In order to capture the different levels of support for clinical hypotheses as expressed in clinical guidelines, the scales may contain bi-polarities and are expressed using modalities in natural language.

3 Meta-Knowledge and Argument Schemes

Novice and experienced clinicians need different levels of support. Where experts reason at a higher level of abstraction, novices need support also for the operational levels of activity, such as gathering data using screening tools, refining and interpreting low level data into observations and findings [Arocha *et al*., 2005]. Just as reasoning activities are transformed along a hierarchy of activity in terms of activity theory with shifts of foci when breakdowns occur [Kaptelinin, 1996], a similar pattern can be envisioned in a hierarchy of argumentation [Mogdil, 2006]. Causes of breakdowns include absence of necessary data, conflicting guidelines, conflicting evidence, conflicting views of a patient case, etc. If these breakdowns are interpreted as opportunities for learning and development, then providing with "meta"-argumentation about screening tools, guidelines and scales, and preferences among these can support development of knowledge and skills in novice clinicians. We focus in the following subsection on the use of guidelines as context of interpretation of clinical evidence, preference orders on these and the use of critical questions.

3.1 Contexts of Interpretation and Preference Orders

Our basic idea is to provide the physician an overview of the evidence in a patient case interpreted within different guideline contexts, represented as sets of schemes. The basic context of interpretation is captured by a set of inference schemes, which uses a Boolean assessment of whether phenomenon, syndromes or diagnoses are present or absent. This set of schemes is sufficient in typical patient cases and is primarily based on the clinical guideline DSM-IV, (see [O'Brien *et al*., 2000] for an overview).

Identifying critical questions that can be used to assess the validity of a scheme argument and was first exemplified in literature by Walton [1996]. In [Rahwan *et al.*, 2007] the critical questions of the form: *Is it the case that x?* can be inferred from nodes providing the answers x. We use the same additional structure of nodes to include the schemes in the argumentation network. There are benefits envisioned of explicitly expressed critical questions in the dementia diagnostic context, since a physician needs to contribute to the reasoning in interaction with an argumentation system. The following represents a few particularly interesting critical questions identified in the basic guideline context of our application:

- CQ1(Dementia scheme): *Do the cognitive disturbances occur exclusively during a delirium?*
- CQ2(Delirium scheme): *Are the cognitive disturbances better accounted for as due to a pre-existing evolving dementia?*
- CQ3(Amnestic state scheme): *Do the cognitive disturbances occur exclusively during a delirium or dementia?*
- CQ4(Alzheimer's disease scheme): *Are the cognitive disturbances better accounted for as due to other medical condition?*

As can be seen there is a circular description in DSM-IV where other causes need to be excluded before a diagnosis or syndrome can be assessed. Co-existence is possible, but the primary cause is what is searched for. CQ1-CQ3 can be answered if adding time relations and progress information. However, in some cases this is not possible to formalize solely using the guidelines. Therefore, the physician can answer some of the critical questions in interaction with a system and some answers are integrated as *rules-of-thumb*, based on clinical practice experience. One such event arises when there is necessary evidence missing in order to proceed in the reasoning process. In this case the user of the system is requested to further examine the patient and gather the necessary data (Figure 2). CQ4 on the other hand requires that all other medical conditions should be accounted for. This is in DMSS solved for the typical cases by using the basic context of interpretation (i.e., a certain set of schemes) that includes the differentiation between the most common dementia diagnoses based on core features, in combination with an answer from the physician that other medical conditions listed as a checklist have been considered.

When inconsistencies arise (in atypical cases) and the basic set of schemes is insufficient, other sets of schemes can be used that handle ambiguities by assessing levels of confidence in hypotheses using modalities. Alternative schemes can also be used if a more elaborate view of a patient case is desired, for instance, to receive confirmation on a set of hypotheses at a certain point in the process. These schemes are built on clinical guidelines, which incorporate different reasoning patterns that generate different types of support for a diagnosis such as *possible*, *unlikely*, *probable* and *excluded*.

A feature may also have different roles in different guidelines, which is captured by the respective schemes. The roles identified are the following: *core*, *suggestive*, *supportive*, *contradictory* and *excluding*. Core, suggestive and excluding features are classified as necessary evidence, causing the request for missing data to be activated. *Supportive* and *contradictory* features are useful primarily in the atypical cases. However, these are not proven to have diagnostic specificity, but add substantial weight to the clinical diagnosis. The magnitude of this *substantial weight* is not specified in the literature. In our framework they are represented using a certain kind of scheme, distinguished from but supplementing the schemes with diagnostic specificity (Step 5 in Figure 3). The characteristic feature of an argument that is valued as *contradictory* is that it weakens the claim it contradicts. Furthermore, an argument, which is valued as *excluding*, *attacks* and may *defeat* a conclusion.

The following is a simplified example of the arguments supporting the reliability level *possible* for the proposition

Alzheimer's disease is present interpreted in a certain guideline context (Step 1 in Figure 2):
{Dementia, *possibly present*; Insidious onset, *present*; Progressive course, *present*; Episodic memory dysfunction, *significant*; Lewy Body dementia, *unknown*}.

Lewy Body dementia represents in the example all the alternative medical conditions to be taken into consideration in the differential diagnosis process. Adding more findings that leads to a revision of Lewy Body dementia to *excluded* will change the confidence in the diagnosis Alzheimer's disease to *probable* (Figure 2).

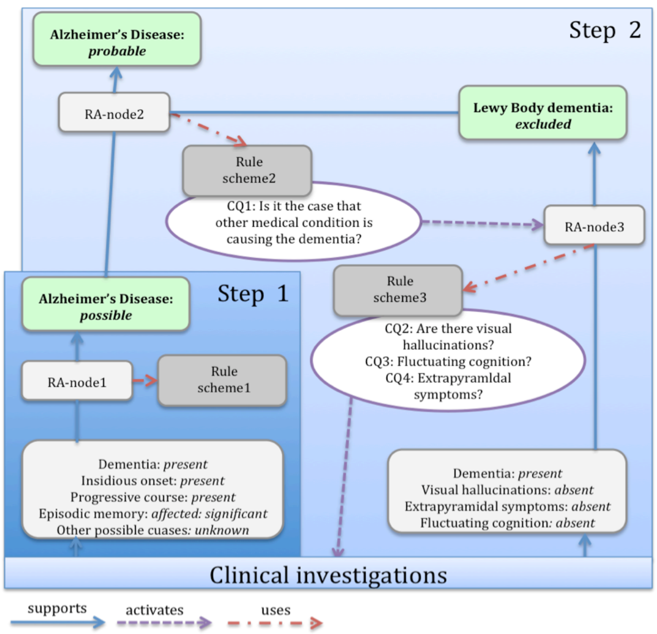

Figure 2. Differential diagnosis using critical questions for increasing confidence in a diagnostic conclusion.

If the revision would instead generate the conclusion *probable Lewy Body dementia*, this attacks the Alzheimer's disease hypothesis and turns the confidence into *excluded* according to two guideline contexts sharing the same conflict scheme (Step 3b in Figure 3). The Lewy Body dementia diagnosis can also be assessed by applying a preference order on the values as defined in a preference scheme. When applied, *probable Lewy body dementia* becomes a stronger assessment than *possible Alzheimer's disease*. However, before Alzheimer's disease is excluded the possibility of a co-existence needs to be taken into account, exemplified in Step 3a in Figure 3. Co-existence of the two diseases is considered having the same amount of support as the diagnosis with the least support, i.e., *possible*. Since this is a rather weak assessment, the assessment in our example becomes *probable Lewy Body dementia* in Step 4. Introducing *supportive* and *contradictory* evidence to the argumentation in this case provides additional strength. Adding a *supportive* premise to the reasoning is exemplified in Step 5 in Figure 3. This generates an indication that supportive features exist and increases the confidence in the diagnosis (in this case the outcome is *probable+*). However, to what extent needs to be valued by the physician in the context of all available information in the individual patient case, taking also the characteristics of the applied guidelines into consideration.

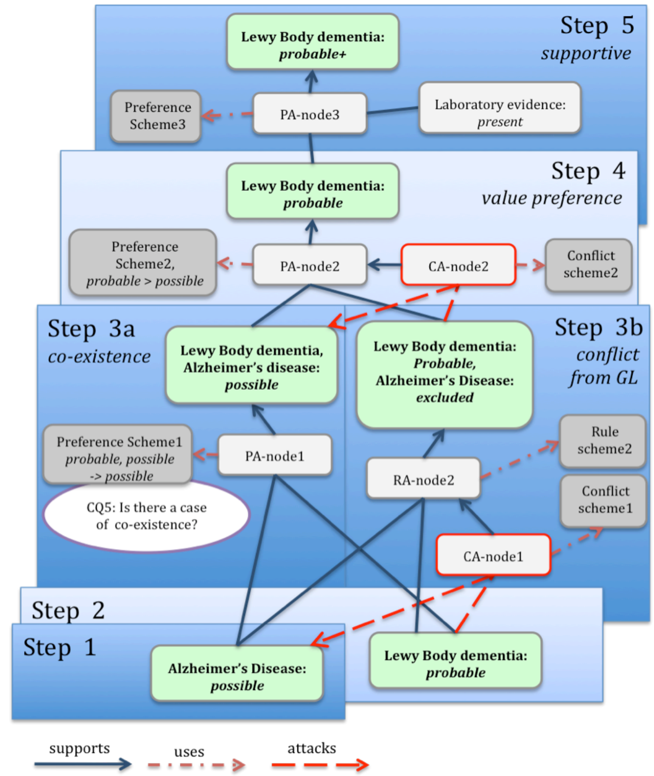

Figure 3. Example of a differential diagnosis process taking preferences, modalities, co-existence and *supportive* feature into account.

Personal preferences and local policies may be influential on the choices of which sets of guidelines to use. Therefore, the possibility to assign a preference order on guideline schemes is integrated, currently as a personal preference and based on characteristics of the guidelines such as specificity and sensitivity reported in evidence-based medicine research. A physician may for instance prefer to use the guideline NINCDS-AIREN for identifying vascular dementia instead of DSM-IV for different reasons [O'Brien et al, 2000]. One reason why DSM-IV may be preferred is that it is more widely spread, and is considered more easily applicable in clinical practice. DSM-IV assess the diagnosis as *present* using a Boolean scale, while NINCDS-AIREN requires more specific evidence and assess a *possible* vascular dementia based on the same evidence, which represents obviously a weaker and more cautious interpretation. While the former guideline reports having high sensitivity, the second reports having high specificity in research literature, which may be preferred in a situation of complicated differential diagnosis. Providing such motives for using one guideline over the other in the valuation of patient information would explain differences in outcomes to the novice physician.

Motives and approaches for incorporating preference orders have been suggested in literature and formal properties have been provided for the law domain in [Bench-Capon and Sartor, 2003] and formal issues are also addressed in [Dimopoulos *et al*., 2008] and [Mogdil, 2006].

5 Summary and Conclusions

The main objective of this paper is to present a work-in-progress on formalizing clinical guidelines and clinical knowledge using argumentation schemes as part of an argumentation framework. A guideline is represented by a set of schemes, each capturing a particular pattern of reasoning expressed in the guideline. Schemes are used for distinguishing between different levels of certainty that guidelines express, or different roles that evidence carries in the reasoning process. Critical questions are used for identifying conflicts within and between guidelines. The conflicts are captured and handled using preference schemes based on medical professionals' preferences, or using meta-arguments valuating these guidelines as aid to the medical professional, who also may contribute with answers. This approach has the potential to enrich the support for clinical reasoning in patient cases with suspected dementia by adding meta-knowledge. Furthermore, by incorporating the clinical guidelines in the formal structure and making them visible, then the physician can immediately acknowledge or refuse the motives for a particular hypothesis based on the interpretation of the clinical guidelines. This way the inferences provided by a system become transparent to the user so that the knowledge integrated in the system can be discussed and developed.

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References

[Amgoud et al., 2008] Leila Amgoud, Claudette Cayrol, Marie-Christine Lagasquie and Pierre Livet. On bipolarity in argumentation frameworks *International Journal Of Intelligent Systems*, 23:1-32, 2008.

[Arocha et al., 2005] José. F. Arocha, Dongwen Wang and Vimla L. Patel. Identifying reasoning strategies in medical decision making: a methodological guide. *J. of Biomedical Informatics* 38(2):154-171, April 2005.

[Bench-Capón and Sartor, 2003] Trevor Bench-Capón and Giovanni Sartor. A model of legal reasoning with cases incorporating theories and values. *Artificial Intelligence*, 150:97-143, 2003.

[Bex et al., 2003] Floris Bex, Henry Prakken, Chris Reed and Douglas Walton. Towards a formal account of reasoning about evidence: argumentation schemes and generalisations. *Artif. Intell. Law* 11(2-3):125-165, 2003.

[Chesnevar et al., 2006] Carlos I. Chesñevar, Jarred McGinnis, Sanjay Modgil, Iyad Rahwan, Chris Reed, Guillermo R. Simari, Matthew South, Gerard Vreeswijk and Steven Willmott. Towards an argument interchange format. *Knowledge Eng. Review* 21(4): 293-316, 2006.

[Dimopoulos et al., 2008] Yannis Dimopoulos, Pavlos Moraitis and Leila Amgoud. Theoretical and computational properties of preference-based argumentation. In Proc. ECAI'08, 463-467, 2008.

[Fox and Das, 2000] John Fox, Subatra Das. *Safe and Sound. Artificial Intelligence in Hazardous Applications*. AAAI Press, The MIT Press, 2000.

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

[Lindgren and Eklund, 2005] Helena Lindgren and Patrik Eklund. Differential diagnosis of dementia in an argumentation framework. *Journal of Intelligent & Fuzzy Systems*,16:1-8, 2005.

[Lindgren, 2008] Helena Lindgren. Decision Support System Supporting Clinical Reasoning Process – an Evaluation Study in Dementia Care. *Studies in Health Technology and Informatics* 136:315-320, 2008.

[Mogdil, 2006] Sanjay Mogdil. S. Modgil. Value based argumentation in hierarchical argumentation frameworks. In *Proc. Int. Conference on Computational Models of Argument*, pages 297–308, Liverpool, UK, 2006.

[Nieves et al., 2007] Juan C. Nieves, Mauricius Osorio and Ulises Cortés. Modality-Based Argumentation Using Possibilistic Stable Models. In 7th Workshop on Computational Models of Natural Argument (CMNA VII), IJCAI-WS, pp 35-41, Hyderabad, India, 2007.

[Nieves et al., 2006] Juan C. Nieves, Mauricius Osorio and Ulises Cortés. Supporting decision making in organ transplanting using argumentation theory. In LANMR'06: 2nd Latin American Non-Monotonic Reasoning Workshop, 2006.

[O'Brien *et al*., 2000] O'Brien, J., Ames, D., and Burns, A. (editors). *Dementia*. Arnold, second edition, 2000.

[Prakken et al., 2003] Henry Prakken, Chris Reed and Douglas Walton. Argumentation schemes and generalisations in reasoning about evidence. In Proc. 9th international Conference on Artificial intelligence and Law ICAIL '03. ACM, New York, NY, 32-41.

[Rahwan et al., 2007] Iyad Rahwan, Fouad Zablith and Chris Reed. Laying the foundations for a World Wide Argument Web. *Artificial Intelligence* 171(10-15):897-921, 2007.

[Walton, 1996] Douglas N. Walton. Argumentation Schemes for Presumptive Reasoning. Erlbaum, Mahwah, NJ, 1996.