A Model for Interaction Design of Personalised Knowledge Systems in the Health Domain

Helena Lindgren and Peter Winnberg

Department of Computing Science, Umeå University
SE-901 87 Umeå, Sweden
{helena,pw}@cs.umu.se

Abstract. This paper presents a terminology model of activity that integrates a common set of features to be used by domain experts in the modeling of knowledge in, and interaction with personalised knowledge systems in the medical and health domain. The model is developed based on theories and methods from multiple research domains in addition to empirical field studies of three application domains with end user prototype applications integrated. Features related to the user such as body functions, roles, motives, skills and preferences were included for personalisation purposes and protocols for designing interaction and reasoning. The model is integrated in a service-oriented architecture underlying Semantic Web applications and is extended with domain specific content in the application projects. Application examples are provided from the dementia domain and from monitoring health related issues in the mining and construction work environments.

Keywords: personalisation, user model, ontology, knowledge modeling, interaction design, clinical decision-support systems, argumentation, AIF.

1 Introduction

The need for knowledge modeling environments that are intuitive and easy to use for the domain expert, and which also allows modeling of interaction and reasoning is addressed in this work. Knowledge acquisition, modeling and representation are complex tasks for which modeling languages have been developed especially, in the medical and health domain denoted task-network modeling (TNM) languages [1]. However, typically it is required an extensive training for medical experts to learn how to use the environment (e.g., [2]), while in what way the integrated knowledge will be mediated to the variety of end user with their different need for support is not taken into consideration. The overall aim is often to create a knowledge system that will promote a common work procedure, following a set of chosen clinical guidelines and treatment protocols for the purpose to reduce errors, increase quality and provide equal care to all patients [1]. However, the problem is that even if guidelines are applied, the basic tasks of data collection and interpretations of observations may remain as subjective and unguided assessments.

Our goal is to create a modeling environment that takes both interaction design and knowledge formalization into account in the development of personalized knowledge

M. Szomszor and P. Kostkova (Eds.): E-Health 2010, LNICST 69, pp. 235–242, 2011.

systems for the medical and health domain. Our focus is on promoting learning and knowledge development in the individual user in the situation where it is needed, without restricting the content of the knowledge systems e.g., to certain clinical practice guidelines since this may leave the basic tasks unguided. The semantic web vision is seen as a means to facilitate the creation of such environment. Therefore, the aim of the work presented in this paper is to develop a terminology model sufficiently generic to function as a common model for the application projects in focus for this work. A generic model is aimed for since there are common structures in activity execution, learning, decision-making, reasoning etc., which relates to a human performing activity in a context, even if the contexts are significantly different. For example, the model should incorporate the necessary features for capturing personalisation, reasoning, evidence-based knowledge, knowledge and skill development in the domains of dementia diagnosis and intervention and monitoring work-related health in the construction and mining industries.

The paper is organized as follows. In the next section methods used in the project are described, followed by the results where the model is described and exemplified from the perspectives of dementia care and work related health. Finally, conclusions are drawn.

2 Methods

Structured analyses based on field studies have been made of the clinical investigation of suspected dementia disease [3, 4] and the investigation of activity dysfunction in older adults for rehabilitation purposes [5]. Activity theoretical models have been used in analyses, which provide tools for capturing the dynamic characteristics of the clinical activity at an organizational level as well as at an individual level such as learning and development [6, 7]. In addition, analyses based on interviews with medical experts have been done of the situation for construction and mining industry workers that may suffer from work-related injuries. Prototypes for the different domains were developed for evaluation purposes.

Available terminologies and disease classifications related to the domains were reviewed and evaluated with respect to their ability to capture the information needed for the three domains. General ontologies, which are not specific to the health domain were analyzed and the ontologies of TNM languages were compared [1].

Based on the results a common terminology model of activity emerged, which forms an upper ontology that is extended in the development of domain specific applications. The model was implemented into an RDF/OWL ontology and integrated into ACKTUS. ACKTUS consists of a service-oriented architecture and common building blocks for the user interface. Prototypes for modeling knowledge and interaction were developed for the different domains based on ACKTUS, however, with the components differently composed and introduced depending on the focus for the domain. The prototypes were used in sessions with domain experts for modeling the knowledge to be integrated in future knowledge systems. In these sessions they translated the content of guidelines and other knowledge sources into a semi-formal structure, based on which they formulated formal rules. In the process, they identified the concepts, terms, scales to value phenomenon, factors for personalization such as motives for use, and structured the knowledge content for visualization and interaction purposes. The common ontology integrated in the prototypes have been evaluated in the sessions and modified based on the results in an iterative process. In this process components were integrated into the model and ontology, which serve as building blocks for interaction design of the end user system, also to be modeled by the domain expert.

3 Results

The resulting ACKTUS ontology incorporates knowledge structures that are common for the different application domains (Figure 1). The following components are included: actor (including role, preferences, body, etc.), tools (including both domain-specific knowledge sources such as clinical practice guidelines and assessment instruments, and *activity protocols* for knowledge and interaction modeling in the ACKTUS system), environment (i.e. work environment including organization, physical equipment, etc.) and activity (e.g. reasoning). In the ongoing collaborative knowledge building work involving domain professionals in different application projects, the ACKTUS ontology is extended with domain specific knowledge and structures. In this work, new sub classes of nodes in the ontology are created as well as instances. In the following sub-sections we describe the major common parts related to actors, tools and reasoning support in more detail. Particularly, we introduce the *activity protocols* that are created in the modeling phase and that serve as tools in the interaction with the end user applications.

3.1 Features for Personalisation: Actor, Organization and Environment

The human actor is inevitably integrated in a context in his or her performance of activity. Therefore, the roles of an instance of a human actor are defined together with related information such as environment, organization, equipment, collaborators, responsibilities, etc. and the personal resources related to the actor such as body functions and structures, motives, skills, knowledge, etc. The model includes users as different types of actors who participate in development of knowledge, as users of knowledge content, professionals, etc. An actor is a human with body function and body structures, which may be in focus for assessments of dysfunction. This human individual in focus for assessment may be the user of the system (e.g., in the work-related health domain) or a patient when the user is a medical professional (e.g., in the dementia domain). An actor also has values, preferences and motives that affect in what way knowledge is to be used and presented in the interaction with the system. Actors can also have different authorization to use parts of the knowledge, to integrate new knowledge and reason about issues. This is mirrored in their professional domain and to which organization an actor is associated. A person can have more than one actor role in the system, such as an geriatrician experienced in the dementia domain can be a *clinician* working at a certain hospital, an *author* of a clinical guideline for the domain (i.e. knowledge source), *professor* at a university and associated to the ACKTUS project as a *domain expert*. Furthermore, an actor can have different levels of skills and knowledge related to different knowledge domains defined in the ontology (e.g., consider the expert in internal medicine who treats dementia patients).

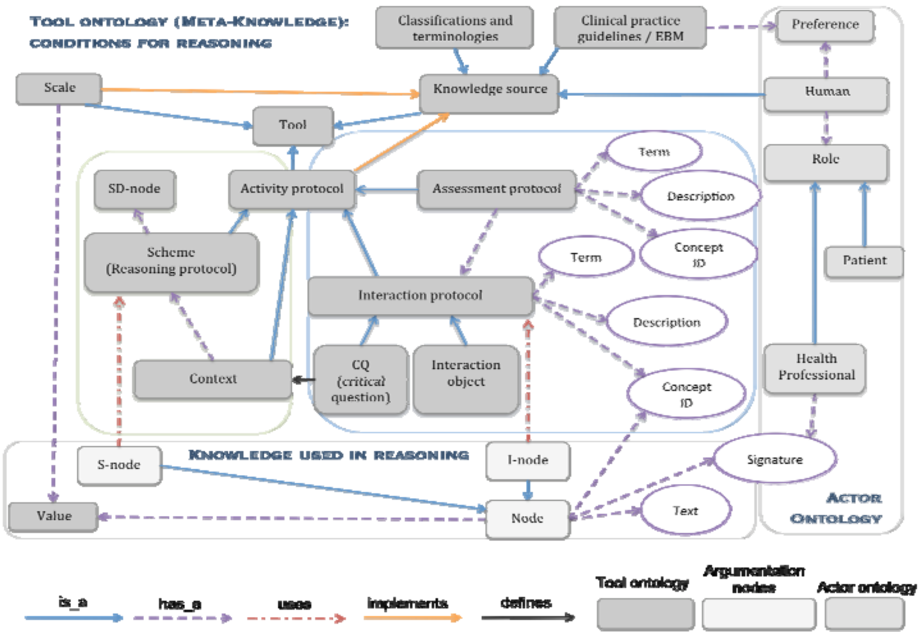

Fig. 1. Part of the ACKTUS ontology. The classes (nodes) are used in the visualization of information and interaction with users to different extent depending on purpose and situation.

As a human, the user has motives, interests, roles, habits, skills and knowledge in domains. Furthermore, the human performs activities associated to an organization and in an environment. Depending on the application domain, these components can be further developed into any level of specificity, relevant to the domain. This is currently done in the manual process of creating *assessment protocols* (Figure 1) to be used for capturing instances of users in the mining and construction industries. In this process the domain experts can include specific information that is used in the tailoring of the interaction and content to an end user. For instance, in the occupational health domain, the content and interaction design is currently based on pre-defined motives that the user may have with using the system (e.g., required to do annual health checkups by law and can do this with the system), domain of interest (e.g., mining industry, pain-conditions), and aspects of their work environment (e.g., exposure to machines that has high measured levels of vibration) in addition to the tailored advice related to an individual's work-related health status (e.g., advice regarding decrease of exposure, change of environment). The flow of interaction is modeled using rules that govern the assessment protocols and related information.

The node *environment* in the ontology contains organization, equipment, etc. We use this class to distinguish between the use environment in a home context, the use environment in a certain mining industry where local information about measured amounts of dust in the air can be included, the use environment a local clinic where the dementia investigation is done in a certain way without radiology equipment, and the use environment related to the knowledge engineering process in the application projects. Different kinds of organizations are typically involved in an application project, e.g. university, industry and/or health care providers.

3.2 Activity Protocols for Modeling the End User's Data Capture Activity

For the domain experts to model the different aspects of knowledge and interaction flows, the ontology was extended with the node *activity protocol* (Figure 1). The activity protocols function as tools, which the end user interacts with in order to execute activity, e.g., reason about diagnoses. *Interaction protocol* is a type of activity protocol and is the component used for supporting the lower-level actions of data collection. The purpose is to provide means to structure the information and promoting a common understanding of the information across professional and organizational borders. The knowledge domain includes features or phenomenon to be assessed, possibly manifested in a person and to be reasoned about. To each feature there are different types of *scales* of values associated, forming an *interaction protocol*. The protocol functions as a structured guideline for assessment and is defined for each feature by the domain professional. After an interaction protocol concerning a feature such as a memory function is applied in a patient case, it may be known if a deficit is present, to which degree this is a reliable assessment and to which degree the symptom is manifested (e.g., *episodic memory*, where *episodic memory* is the English term of the concept, it may be *absent*, *unknown* or *present*, if present, the severity may be *mild*, *moderate* or *severe*). The patient-specific information is generated when the protocol created for the phenomenon is applied. The outcome can be used as a belief about a patient (*I-node* in Figure 1) in the creation of argumentation in the collaborative knowledge building process. It can also be associated to a human actor (e.g. a patient) to be used as part of an argument in reasoning about causes and intervention.

The features and suitable scales are extracted from *knowledge sources* such as clinical practice guidelines, consensus guidelines and general medical literature. These sources have authors (a type of actor) and other information typical for literature on the web. Different types of actors related to a knowledge domain can also function as sources of informal knowledge (i.e. rules of thumb). These can be both professionals associated to an organization, and non-professionals related to a patient within a family context. The content of these sources that relates to reasoning for reaching conclusions is interpreted into instances of *schemes* in the ontology and can be visualized to the user for learning and explanation purposes. While interaction protocols are used for lower level reasoning about data capture, *schemes* support and guide higher-level reasoning and decision making (Figure 1). Argumentation 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 [8]. Executable rules are modeled as *Scheme-application nodes* (*S-nodes* in Figure 1) based on a scheme and consequently, they implement a knowledge source such as a clinical guideline. The S-nodes and I-nodes are used in the construction of arguments, where I-nodes represent the premise and conclusion components of an S-node in a reasoning process. These nodes constitute the basic components of the Argument Interchange Format (AIF) [9], which is a draft for the ongoing development of a formalism to be used for sharing, editing and visualizing arguments over the world wide web.

There are commonly *critical questions* associated to an argumentation scheme that function as activators of arguments for different purposes (e.g., [10]). Critical questions are typically regarded as defeaters of the argument instantiating a scheme, but can also identify valid lines of reasoning that further support the argument [10]. A critical question is in our ontology modeled as a type of *interaction protocol* (e.g., *Is depression a better explanation of the cognitive deficits than dementia?*, which has the scale values *yes*, *no, unknown*).

3.3 Activity Protocols for Personalized Flow of Reasoning and Learning Support

In order to represent flows of reasoning and interaction two additional activity protocol classes are defined. These are *reasoning context* (collection of schemes) and *assessment protocol* (ordered collection of interaction protocols). At a superficial level, and in the view of the end user, an interaction protocol corresponds to a collection of interface components for collecting information about e.g. a symptom or phenomenon, and the assessment protocol can be presented to the user in a standard web form. Assessment protocols can contain other assessment protocols. Depending on the future end user and the use context, the assessment protocols are presented differently, in order to tailor the interaction and content of information to the end user. The tailoring can be modeled using S-nodes with an assessment protocol as conclusion node (e.g. if a mining worker has symptoms and is interested in knowing more about machines, the protocol about machines can be activated with associated contextual information for his or her work environment).

The activities can be structured in an implicit hierarchy with critical questions to be answered associated to each sub-action. In the system this can be done by defining *reasoning contexts* that are associated to a critical question that can be used as part of a control flow in a reasoning process (e.g. *Is depression a better explanation of the cognitive deficits than dementia?* which activates the reasoning context containing schemes related to depression). The critical questions are used for activating reasoning, defining goals and for finding conclusive endpoints, for instance in a differential diagnostic process. The reasoning contexts resemble the nested plans occurring in e.g., Asbru [1]. However, it should be noted that there is a difference between the loosely coupled reasoning contexts as defined by critical questions and the common notion of plans as typically modeled in the task-network modeling languages. The reasoning contexts associated to a knowledge domain such as the dementia domain, can be activated from any view point that the user may have that relates to a feature modeled within the ontology for the domain. For instance, ideally a physician starts with collecting the information needed in a patient case and reason in an inductive, diagnostic forward-chaining manner, corresponding to a common perception of how e.g., the investigation of a suspected case of dementia should be executed (i.e. a type of plan). However, often a physician has early in the process a hypothesis about a diagnosis, which he or she may want to evaluate and as a starting point, possibly due to time limitations. If the essential information is not collected, the critical questions will alert the physician about this, and a conclusion can be made, either based on limited knowledge, which the physician will then be aware of, or based on additional information collected in interaction with the different reasoning contexts and assessment protocols activated in the process. The locution of reasoning will then follow the order that the user chose to reason about topics, however, guided by the reasoning contexts. One particular important feature is that in the case the physician chooses to deviate from a guideline, he or she will be able to easily include motives for this in a formalized way, so that this knowledge is feed back into the system and reused as a rule-of-thumb, included in the user agent's belief base.

In terms of activity theory a critical question triggers a conflict, which may cause a breakdown situation, with a corresponding shift of focus, lead by the topic of the question [8]. The critical question either challenges an assumption or provides a different view of support for an assumption (consider again the example *Is depression a better explanation of the cognitive deficits than dementia?*, where there is a shift of focus from dementia to depression). When a conclusion is reached, this conclusion can be used to continue an action possibly at a higher level in the reasoning activity that was interrupted by the challenging critical question. Another example from the dementia domain is when the question about what is actually known about a patient's memory function is activating a sub-action. If the user has not developed the necessary skills in assessing memory dysfunctions, a breakdown situation occurs and this typically operational task for the experienced physician is turned into a goal-driven action for the individual to be performed at a conscious level. The goal then becomes defined by the critical question that triggered the action, and the answering of the question to generate the required information becomes the goal. If the user actually is completely ignorant about e.g., memory types, the triggered action can even turn into an activity in the sense of activity theory, with the individual's motive and need to become educated driving the activity, moving focus away from the original activity to investigate the patient. In this situation, a more extensive support should be provided the individual, for instance, explanations and case descriptions of manifestation as supplements to definitions of memory dysfunction. Also concrete methods to assess dysfunction possibly in the form of validated clinical assessment instruments can be provided. This additional support is provided by the assessment protocols.

4 Conclusions

This paper describes the model of activity implemented in the prototype system ACKTUS that is currently being developed for knowledge and interaction modeling in the dementia domain, in the rehabilitation domain of older adults and in the domain of occupational health in the mining and construction industries. The system is based on a web service architecture allowing for multiple knowledge repositories that can be shared between applications. The model is extended with domain specific content in the application projects. The model incorporates the argument interchange format AIF for editing and visualizing schemes, arguments and reasoning and for reusability purposes. For providing support for reasoning and for designing flow of activity additional nodes were included as protocols for interaction. Particular features related to the user such as body functions, roles, motives, skills, habits, etc., were also integrated for personalisation purposes. Furthermore, the model incorporates contextual components such as the environment and equipment used in activity. Functionalities are included that support the development of the knowledge as an international distributed collaborative work, using the semantic web.

Acknowledgments. The project is partly funded by the Swedish Brain Power, VINNOVA and Emil and Wera Cornell foundation.

References

1. Wang, D., Peleg, M., Tu, S., Boxwala, A., Greenes, R., Patel, V., Shortliffe, E.: Representation primitives, process models and patient data in computer-interpretable clinical practice guidelines: A literature review of guideline representation models. I. J. Med. Inform. 68(1-3), 59–70 (2002)
2. Seyfang, A., Miksch, S., Marcos, M., Wittenberg, J., Polo-Conde, C., Rosenbrand, K.: Bridging the Gap between Informal and Formal Guideline Representations. In: Brewka, G., Coradeschi, S., Perini, A., Traverso, P. (eds.) ECAI 2006. Frontiers in Artificial Intelligence and Applications, vol. 141, pp. 447–451. IOS Press, Amsterdam (2006)
3. Lindgren, H., Eriksson, S.: Sociotechnical Integration of Decision Support in the Dementia Domain. Stud. Health Technol. Inform. 157, 79–84 (2010)
4. Lindgren, H.: Towards personalised decision support in the dementia domain based on clinical practice guidelines (to appear in UMUAI)
5. Lindgren, H., Nilsson, I.: Designing Systems for Health Promotion and Autonomy in Older Adults. In: Gross, T., Gulliksen, J., Kotzé, P., Oestreicher, L., Palanque, P., Prates, R.O., Winckler, M. (eds.) INTERACT 2009. LNCS, vol. 5727, pp. 700–703. Springer, Heidelberg (2009)
6. Kaptelinin, V., Nardi, B.: Acting with technology: Activity theory and interaction design. The MIT Press, Cambridge (2006)
7. Lindgren, H.: Personalisation of Internet-Mediated Activity Support Systems in the Rehabilitation of Older Adults – A Pilot Study. In: Grasso, F., Paris, C. (eds.) Personalisation for e-Health, Verona, pp. 20–27 (2009)
8. Bex, F., Prakken, H., Reed, C., Walton, D.: Towards a formal account of reasoning about evidence: argumentation schemes and generalisations. Artif. Intell. Law 11(2-3), 125–165 (2003)
9. Chesnevar, C., McGinnis, J., Modgil, S., Rahwan, I., Reed, C., Simari, G., South, M., Vreeswijk, G., Willmott, S.: Towards an Argument Interchange Format. The Knowledge Engineering Review 21(4), 293–316 (2006)
10. Tolchinsky, P., Modgil, S., Cortés, U.: Argument schemes and critical questions for heterogeneous agents to argue over the viability of a human organ. In: AAAI Spring Symposium Series; Argumentation for Consumers of Healthcare, pp. 377–384 (2006)