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Knowledge Engineering as a support for building an Actor Profile Ontology for Integrating Home-Care Systems

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Abstract. One of the tasks towards the definition of a knowledge model for home care is the definition of the different roles of the users involved in the system. The roles determine the actions and services that can or must be performed by each type of user. In this paper the experience of building an ontology to represent the home-care users and their associated information is presented, in a proposal for a standard model of a Home-Care support system to the European Community.

Keywords. Home-based eHealth, Decision Support and Knowledge Management, Health Information Systems, Telehealth, Distributed Systems, Knowledge-based systems, Concept representation-preservation, Home-care.

Introduction

K4CARE is a project financed by the European Commission devoted to develop an intelligent web platform to provide e-services to health professionals, patients and citizens involved with the Home Care (HC) of elderly patients living at home. Those services aim to improve the capabilities of the new EU society to manage and respond to the needs of the increasing number of senior population requiring a personalized HC assistance. From a medical point of view, one of the main goals of the project was to identify which were the common and basic home care structures shared by the main sanitary systems in Europe. They are called HCNS (Home Care Nuclear Services) and they comprise the minimum elements needed to provide a basic HC assistance. From a technological point of view, the K4CARE project aims to provide an intelligent platform which can support HCNS management and also, possible later extensions to specialized services such as those coming from Oncology or Rehabilitation units ([1],[2]), these are called HC Accessory Services (HCAS).

To build a platform that supports such a complex HC model is not a trivial task and requires a careful design. In the K4CARE project, the platform is implemented using a multiagent system, which facilitates the interaction between different types of wireless devices, the communication between different components and the distribution of tasks according to the medical roles. Another critical part of the construction of such a complex system is the design of the information system storing the knowledge which describes the behaviour of the platform. In this project this has been modelled using ontologies [3], a formalism widely used in Knowledge Engineering, AI and Computer Science, which provide a formal frame to represent the knowledge related with a complex domain, as a qualitative model of the system.

However, to build the ontology of a phenomenon as the one faced by the K4CARE project is a huge and a very complex task, because a great number of services, people and institutions are involved in the HC, and it is very difficult to find a formal representation to express all the interactions among the components of the system. The medical knowledge that the K4CARE platform has to manage is represented in different Knowledge Sources, due to their different functionalities in the system [4]. One of those knowledge sources is called APO (Actor Profile Ontology) and it is devoted to contain all the knowledge about the different kind of actors involved in a HC assistance system and their potential functionalities and possible interactions. Thus, APO is defining the knowledge behind the global behaviour of the system and the services provided. The purpose of the APO is to facilitate the integration and coordination of the different actors that are needed to assure a good HC assistance, since the APO clearly defines what and how care will be done in this new HC model.

Describing the design, the contents, and the role of the APO are the focus of this paper, as well as to insist on the problematic related with the construction of this kind of ontologies when real systems that support very complex real domains are constructed. A deeper understanding of the robust, consistent and reliable management of APO comprises a methodology and several tools focused in another paper ([5]).

In the following section, we describe the contents of an ontology and a formal methodology for building ontologies. Section 2 is devoted to explain how this methodology has been applied to build the APO and the results obtained at each stage, including the main details about the contents of the APO. Finally, section 3 highlights the main aspects of this work and presents the conclusions.

1. Materials and methods

Ontologies

As said before, the APO is an ontology. In [3] ontology is defined as a formal, explicit specification of a shared conceptualization, which provides an abstract model of some phenomenon by identifying the relevant concepts of that phenomenon. Ontology captures the common knowledge, that is, not a personal view of the target phenomenon of some particular individual, but one accepted by a group. In our case, this group is formed by the different medical partners of the K4CARE project, which include people from eastern and western European countries. There are different ontology knowledge representation formalisms, all of them sharing 3 common components:

- **Classes:** they represent concepts taken in a broad sense.
- **Relations:** they represent a type of association between concepts of the domain. Binary relations are sometimes used to express concept attributes.
- **Instances:** they are used to represent elements or individuals in the ontology.

Ontology Engineering

The set of activities that concern the ontology development process, the ontology life cycle, the principles, methods and methodologies for building ontologies, and the tool suites and languages that support them is called Ontological Engineering [6]. With regard to methodologies, several proposals exist, among which On-To-Knowledge [7] is the one used here. It is based on five steps:

- Feasibility study, which is the basis for next steps.
- Kickoff: devoted to establish the ontology requirements specification documents. These documents define the domain and the goal of the ontology, the design guidelines, the available knowledge sources, the potential users, and the use cases. Due to the particular complexity of the K4CARE system, and the aim of establishing European standards for K4CARE, the Kickoff is developed by means of a panel of medical and social experts in the field of geriatrics and home care.
- Refinement: it is addressed to obtain a mature ontology in two steps, taking as a basis the initial specification provided in the kick-off.
    - Knowledge elicitation with domain experts. This is a very critical step, since lots of implicit knowledge is unconsciously used by experts in their daily reasoning. This knowledge is crucial for correct modelling and usually does not appear in the kick-off specification. This missing knowledge produce inconsistencies, redundancies or incompleteness that may cause wrong performances of the Ontology
    - Formalization: Once a consistent, non-redundant, and presumably complete description of the domain is clear, proper classes and relations that correctly formalize it have to be identified.
- Evaluation: to prove the correctness and usefulness of the ontologies:
    - Checking the requirements and competency questions
    - Testing the ontology in the target application environment.
- Maintenance: On-To-Knowledge proposes to carry out ontology maintenance as a part of the system software.

2. Results

In this section the most significant results of the ontology building are presented.

Kickoff: The result of the experts panel process is the ontology requirements specification document, where the Nuclear Home Care Services to be supported by the K4CARE platform are specified, together with the actors involved, including all sort of professionals (patient, relatives, citizens, and involved social organisms), the tasks they can perform to complete medical services, the processes where they take part, the documents they will exchange and the kind of access they will have to the information generated as a result of those activities.

Refinement: Two steps compose this phase:

- Elicitation: The interaction between knowledge engineers and medical experts identified some missing elements in the original specification. As a consequence:
    - A detailed specification on how the different services will be performed was made. A procedure was associated to every service indicating which steps

must be performed to carry out the service. This is codified using the SDA (State-Decision-Action) formalism [10].
  - o The list of documents needed for any service is detailed.
  - o The professional performing the steps involved in a procedure is specified.
- Formalization: According to the specification provided by experts, different hierarchies of concepts have been defined together with the relationships between them. Section 2.1 provides more details about them. The APO ontology is coded in OWL [8] language, using the Protégé tool [9]. APO represents the home-care knowledge by means of classes and relationships, without instances. Particular data is placed in the Administrative Data Base and the Electronic Health Record of the system.

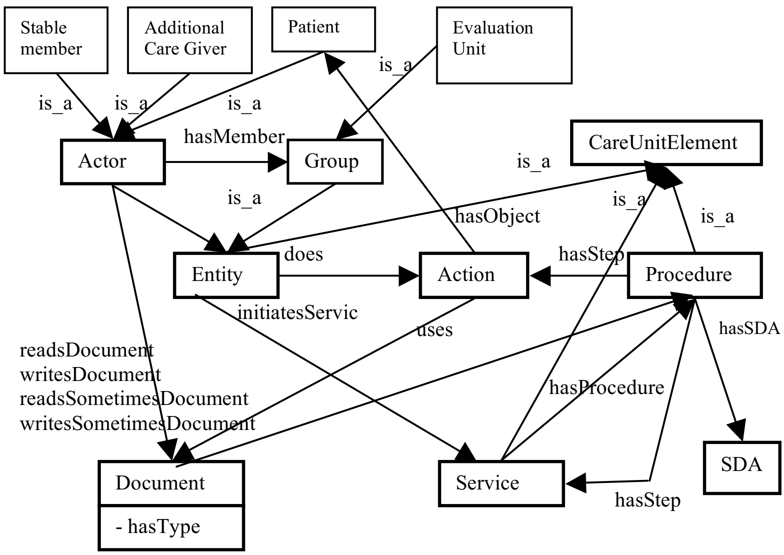

Figure 1. APO architecture

Evaluation: The consistency of the APO has been reviewed by a panel of experts and at present it is included in a prototype of the platform to be tested in a minor Italian county with real HomeCare assistance to a real sample of elderly patients.

Maintenance: In this particular context APO is storing static knowledge about the HC system, related to HCNS. However, in the long term it will be interesting to keep the possibility of enlarging the APO with specialized services (oncology or rehabilitation), which are specific of a certain context (a country, a hospital, etc.). In [5] a specific methodology to enlarge APO with consistency and robustness is presented, and a software tool called ISA is developed to assist this task. Rehabilitation services have already been successfully added to the APO using this methodology.

2.1. Details about APO contents:

The main concepts of the APO are described below:

The **Entity** concept refers to all the people or groups involved in the HC. Entity is subdivided into two main classes: Group for working teams with healthcare liabilities;

Actor, for individual participants (patient, stable members such as nurse, physician in charge of the patient, head nurse, social worker, family doctor and additional care givers). Entities store information about the services they can initiate and the actions they can perform. Actors also have some rights over Documents they can read or write.

In the K4CARE Model, a **Service** is defined as a HC activity that involves the work of one or more HC actors in a coordinated way. They are classified into Access Services (management services), Patient Care Services, and Information Services. The property serviceInitiatedBy informs about the entities that are able to activate the service (i.e. capabilities and liabilities), while hasProcedure can indicate one or more alternative ways of performing that service by means of procedures. Finally, hasDocument binds documents that may be required in the achievement of that service.

Actions represent the single steps that should be done to perform a service. The ontology distinguishes many subtypes as social action, case management action, back-office action, nursing action, etc. Actions have an object (hasObject property) that receives the action (usually a patient), and a subject (hasSubject property) that is the entity able to perform that action. Actions can also work over one or several documents (usesDocument property).

A **Procedure** is the representation of the way a Service is provided in terms of the available actions and the rest of services. It stores information about the referred service the procedure represents (isProcedureOf property), the steps of the procedure (hasStep property) or actions and services involved in the provision of the service and the SDA algorithm that defines how the procedure must be applied, that is, which is the flow of actions (property hasSDAFile). Different care units can have different SDAs for the same procedure, for this reason the ontology includes also the concept **SDA.**

Documents model the communication between Entities all along Service performance. They can be used in different Procedures (property isDocumentOf), and can be used by different Actors with different rights (properties isWrittenBy, isWrittenSometimesBy, isReadBy, isReadSometimesBy).

Every leaf class of the hierarchies of concepts Entity, Service, Procedure and SDA inherits also from the **Care Unit Element** hierarchy. This permits to indicate which Care Unit they refer to. For every new HC accessory service (HCAS) used to extend the capabilities of the K4CARE Model, the APO must have a new subclass of Care-UnitElement with the name of the new HCAS (e.g. rehabilitation, oncology).

3. Discussion, conclusions and future work

This research is involved with modelization of domain knowledge for building an intelligent platform supporting the HC assistance of elderly people. The starting point is the proposal elaborated manually by a panel of experts defining the standards of HC in future EU countries [1]. The proposal integrates the best practices of old and new EU countries in a handbook of good medical assistance to ill, disabled, chronic senior patients in a technological society. Defining this standard required a huge effort from the medical partners of the project, who had to formalize the behaviour of a HomeCare system as precisely as possible, in a structured way. This process made explicit valuable medical knowledge that was not available before and that was the input of this work. Expert's proposal in [1] identifies which are the HCNS. This document constituted a general specification at the medical level that required deeper formalization at the engineering level, since some relevant information was missing.

In Knowledge Engineering it is well-known that formalizing complex domains is a very difficult task, mainly because of existence of implicit knowledge, which is rarely expressed in a first expert's specification. Knowledge engineering helps to refine and formally validate the medical model in terms of correctness from a logical point of view. High interaction between experts and knowledge engineers is required in this step and good collaboration was achieved in this project. Non-trivial redundancies, inconsistencies and lack of information needed to complete the specification were identified. The correctness of the APO is critical for a good performance of the system.

Finally, APO was internally organized to mimic the real structure of HC assistance, and its internal architecture was designed to be flexible enough for supporting later enlargements with new specialized care units.

Currently, a first prototype of the K4CARE platform is being implemented and future tests in real scenario are in progress. APO plays a crucial role in the global architecture of the system, since it is defining the tasks that each user is allowed to do. Moreover APO is defining permissions and interactions between the different people involved in the HC assistance, from the patient itself, to the main professionals as family doctors or social workers, what opens the door to having a real integrated assistance in real time. This work is an application of the knowledge engineering methodologies to a real domain and a meaningful scenario describing HC was successfully modeled.

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