Customization of an agent-based medical system

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Abstract. In this paper, the automatic customization of an agent-based medical system is approached by means of ontologies. The particular case of Home Care studied and developed in the EU K4Care project, is presented. The customization is achieved by means of generating individual versions of a reference ontology, called Actor Profile Ontology, which defines the behaviour of the actors in the multi-agent system. The paper, analyses the usability and advantages of this customization in order to add flexibility and adaptability to the system. It also shows how the personalized ontology is able to represent the liabilities and permissions of a particular user, providing the base for automatically generating the behaviour of the corresponding personal agent. A tool, called ATAPO, is also presented. It has been designed to assist the user in the personalization process. The way how this tool interacts with the system to permit the online modification of the behaviour of the agents is also discussed.

Keywords. Personalization, multi-agent systems, ontologies.

Introduction

New health care systems aim to provide the so called user-centred approach, which consists on adapting the interface and even the behaviour of the system to the user requirements. In this way, the system is better accepted than traditional systems [14].

In the K4Care project (*Knowledge-Based Homecare eServices for an Ageing Europe*), supported by the European Commission, this issue has been addressed. The main goal of the project is to develop an intelligent web platform for providing e-services to health professionals, patients and citizens involved with the care of elderly patients living at home.

The care of senior patients that suffer chronic diseases requires life long treatments under the continuous supervision of a group of people in charge of providing medical care.

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It is now widely recognized that hospitalization is sometimes not related to the patient's acute medical condition, but to the need for rehabilitation or for social reasons. Hospitalization in these cases is therefore seen as both inappropriate and costly.

In that sense, Home Care (HC) is considered fundamental to provide long term care to senior people. HC is conceived as the integration of medical, social and familiar resources addressed to allow the care of the patient in his own environment [4].

In the initial stage, a general model of HC treatment in European countries has been defined [5]. This has been done by integrating the expertise of specialized centres and professionals of HC of several old and new EU countries. This model is easily adaptable in any of the EU countries [5]. The HC model has been formally represented by means of an ontology [6] called Actor Profile Ontology (APO). The APO contains information that defines the profile of the users of the system, defining their liabilities and permissions inside the medical organization.

This HC model is supported by a web-based intelligent platform (K4Care system) that provides e-services to the users, called *actors* (health care professionals, patients, relatives and additional care givers). All actors are represented in the system using a multi-agent system [13] that coordinates all the activities involved in daily home care. The agents use the knowledge in the APO to guide their behaviour, for example, to customize the functionalities available to each particular user or to schedule activities [8].

Within this approach, the customization of this web application can be done by means of the tailoring of the contents of the APO for each particular user. The customization process permits to obtain a personal *subAPO* for each user [2], which is automatically used by the system. As it will be discussed along the paper, this knowledge-driven approach provides a very flexible architecture that allows changes in the definition of the user's profile at runtime, automatically modifying the behaviour of the agents. Thus, the system is continuously adapted to each new situation because the ontologies model, not only static organizational knowledge, but also the dynamics of the organization.

The tailoring process has been explained in [2]. The focus of this paper is the use of the personal suAPOs to determine the behaviour of the system and customize the interface according to the current personal profile of each user.

The paper is organized as follows. Section 2, briefly makes a description of the content of the Actor Profile Ontology. Section 3, explains the tailoring process and how it is used to build personal subAPOs. Section 4 is devoted to explain the customization of the K4Care system, where two parts are needed: the tailoring tool (ATAPO) that generates the subAPO and the multiagent system that exploits the personal knowledge in these subAPOs.

1. The Actor Profile Ontology

Ontologies are a new paradigm for representing knowledge in a structured way that facilitates the reasoning on it [12]. They have been widely used in medicine [9], although they have been usually exploited to represent medical terminology, as well as to model static healthcare entities and its relations.

The Actor Profile Ontology (APO) stores the organizational knowledge of the K4Care HomeCare model. It states the common and basic HC structures shared by the main sanitary systems in Europe as the minimum elements needed to provide a basic HC assistance, according to the HC model proposed in the K4Care project [5].

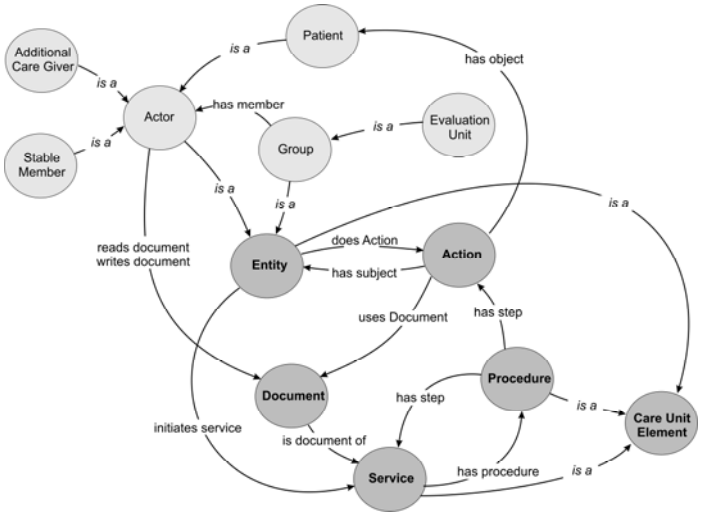

Figure 1. General structure of the Actor Profile Ontology.

The K4Care HC model, represented in the APO (Figure 1), consists of 6 basic components, which are top concepts of the ontology, linked with different semantic relations. The main classes in the ontology are the following: *Entity* refers to all the persons (*Actors*) or *Groups* of persons involved in the model. *Service* is defined as a HomeCare activity that involves the work of one or more HC Actors in a coordinated way. Each service is provided according to an established *Procedure*, which consists on a list of specific *Actions*. The Actors, according to their competencies, have some liabilities on the Actions. During the execution of an action, some *Documents* may be required. They store the personal and medical information of the patients. Actors also have some pre-defined permissions to read/write the documents. Different Care Units can be modelled using this structure. The class *Care Unit Element* must contain, at least, the basic care unit denoted as HCNS (HomeCare Nuclear Services). However, the model allows enlargements with new HomeCare Accessory Services (HCAS) with specialized services such those coming from Oncology or Rehabilitation units [6].

Most of those top-level concepts have a hierarchy of sub-concepts that permits to distinguish different subtypes, building different taxonomies with *is-a* relations. For example, in Figure 1, three subtypes of Actor are shown: Additional Care Giver, Stable Member and Patient. Other taxonomical relations exist to classify Documents, Procedures and Services.

2. Tailoring of the Actor Profile Ontology

Tailoring is the action of adapting general knowledge to a particular case. In this work, the tailoring process is devoted to extract sub-ontologies (*subAPOs*) from the reference APO, providing a particular view of the general ontology restricted to some conditions. With regards to an organizational ontology, the tailoring has the goal of obtaining sub-ontologies with a subset of concepts and relations that participate in some part of the activities of the institution. In the K4Care project, two cases of tailoring were defined according to the requirements given by the medical experts [2]:

- *Tailoring of Care Units*: generates a subAPO with the information regarding a specific care unit (e.g. a subAPO with information about the Rehabilitation Care Unit).
- *Tailoring of Entities*: this type of tailoring regards to the different Actors or Groups of actors in the HC model. It generates a subAPO with the information regarding a particular type of actor (e.g. subAPO of the Family Doctor role in the organization).

As result of the tailoring process, a new ontology is created: the *subAPO* maintains the structure of the APO, that is, the concepts that appear in the subAPO are organised according to the same taxonomies and maintain the same relations, properties and restrictions than the reference APO, but only those referring to some care unit or entity.

The possibility of having the information of a particular actor profile in a separated ontology is interesting for two reasons: (1) to have a view of all the elements that are related to a particular actor profile. In fact, the actor profile is storing the way in which a certain kind of actor is participating in the HC assistance. (2) To have the possibility of customize the subAPO of a particular user, building a personal ontology that describes the way the user wants to participate in the system.

This latter point is the one that is addressed in this paper. As it is usually claimed, the personalization of the health care system is important for the interaction between the user and the system. It contributes to the acceptance of medical user-centered systems [14].

With regards to an Actor Profile Ontology such as the one presented in this paper, the personalization process permits to re-define the role and permissions of the user in the system. However, in health care, actor's liabilities are strictly defined and this issue constraints the potential of the customization in such systems.

After a detailed evaluation of several personalization possibilities, medical experts and knowledge engineers agreed on considering the following cases [2]:

- **Documents personalization**: consists on providing to a concrete user the possibility of consulting some extra documents, originally not permitted to him according to the standard definition of his actor role, but that are needed in some particular situations.
- **Actions personalization:** Although the set of possible actions to be performed by actors are strictly defined inside the K4Care model, there are some actions that can be performed by more than one type of actor. In real life, agreements between actors can lead to a particular distribution of tasks for some period of time. In these situations, actors can personalize their ontology by removing some of the Actions associated to his/her profile.

These personal changes in the actor's profile are valid for some fixed period of time. In the first case, the access to some document is usually only required for the assessment of some patient's condition. In same way, the actions personalization corresponds to some agreed distribution of tasks between a team during some days. For this reason, this temporal information is stored using new relations between the concepts of the ontology. When the situation finishes, the actor orders the reversion of the changes and those new temporal relations are removed from the ontology [2].

Having the possibility of providing these two functionalities greatly improves the behaviour of the system, because they support quite usual situations in health care organizations, which cannot be formalized in a static model.

To facilitate the automatic tailoring and personalization tasks to the K4Care users, a tool called ATAPO [2] (*Automatic Tailoring of the Actor Profile Ontology*) has been implemented. This tool provides a graphical and user-friendly interface that supports the two types of tailoring presented above. Moreover, it permits to personalize the subAPO to the user's requirements, regarding documents and actions management.

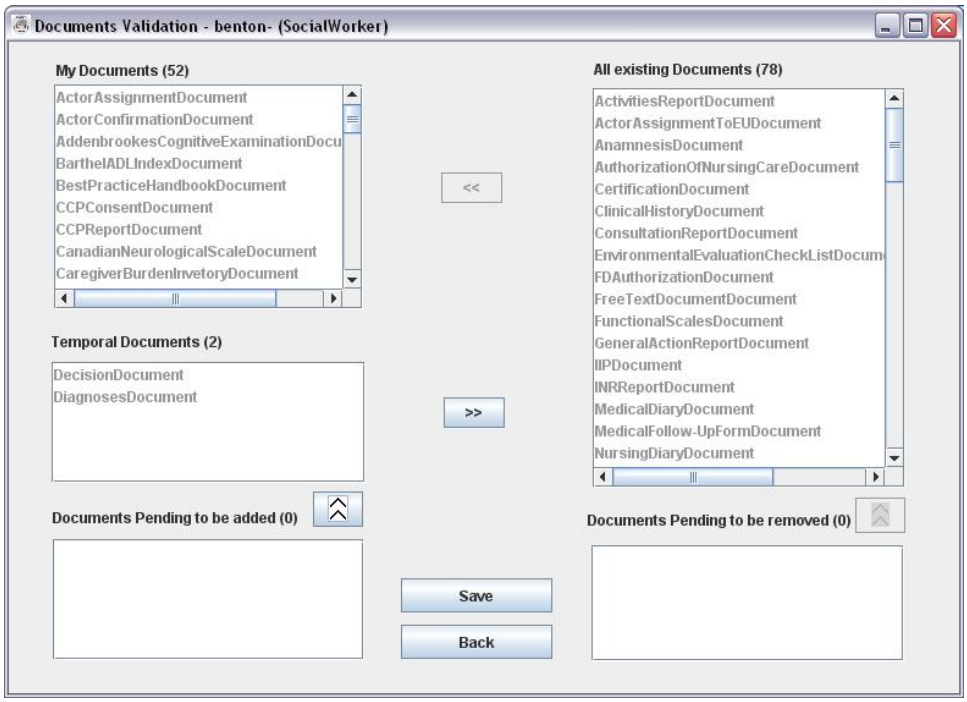

Figure 2. ATAPO interface for documents access personalization

It is important to stress that this personalization tool controls that any modification in the profile made by a user is valid according to the general Home Care model, in order to avoid, for example, that the user could do an action for which he is not competent. For

example, patients cannot give an order to initiate any medical service. In addition, any change in the predetermined user profile requires the authorization of the corresponding care unit head (usually a Physician in Charge or a Head Nurse), as responsible of the good performance of the process and safe conservation of information, in particular to that information which concerns privacy issues. This process is also supported by the ATAPO tool, but it is out of the scope of this paper (details can be found at [2]).

In Fig. 2, Mr. Benton, a social worker, has been authorised to read the Decision Document and Diagnoses Document of his patient. Those documents are produced at the first assessment of a new patient. Although they are not initially available to social workers, in this case, the Physician in Charge has considered that the request of Mr. Benton is acceptable due to the special condition of his patient.

3. K4Care system customization

In the K4Care project, a web-based platform has been developed to support HC assistance of senior and disabled people in a distributed way. In Figure 3, the client-server architecture of the K4Care system is shown. On the server side, we have a set of *Knowledge Resources*, including an electronic health record (EHR) [1], the *Actor Profile Ontology*, the medical domain knowledge stored in an ontology called *Case Profile Ontology* (CPO) [10] and a repository of the procedures that describe the medical know-how as *Formal intervention plans* [11]. We also have the intelligent components of the system: the *Multi-agent System* [8] and the *Data Abstraction Layer* (DAL) [3].

On the client side, two applications have been built. The ATAPO tool only devoted to the tailoring of the system and the K4Care Web interface, which provides to the users all the HC related functionalities. The connection between the client systems and the server is done through some *servlet* functions.

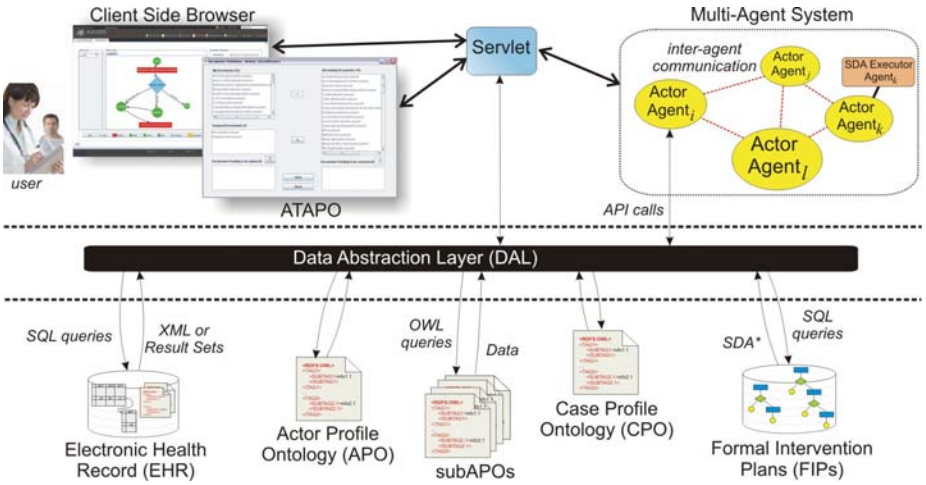

Figure 3. Access to the K4CARE data in an integrated way

The multi-agent system embeds all the system logics by agentifying the actors involved in HC services. Agents act semi-autonomously, in the sense that several actions, such as exchange of information, collection of heterogeneous data concerning a patient (results, current treatment, next step, past history) or the management of pending actions are performed by agents without the intervention of human users.

As each source of knowledge is represented in a different format, an intermediate layer *Data Abstraction Layer* (DAL) has been designed with the aim of providing high level functionalities for accessing the Knowledge Resources. Then, the remaining components of the system do not need to know neither the internal organization of the data nor where they are located (data is distributed). In addition, the DAL is in charge of the control of the data access according to each user's profile.

Concerning the customization of the system, the DAL permits the coordination between (1) the personalization (or tailoring) tool, ATAPO, in charge of building new ontologies that describe the personal profile and (2) the agents that are able to use the appropriate ontology for retrieving the personal profiles to act accordingly. As it is represented in Fig. 2, all the requests to the knowledge resources are managed by the DAL. Therefore, the DAL is the intelligent component that knows which is the subAPO of each user and provides the information according to this personalized ontology. If a user does not have any personal subAPO, then the general APO is used to answer the queries.

3.1. Tailoring using the ATAPO tool

Although the aim of this paper is not providing a detailed description of this tool, here, the ATAPO processes are referred with respect to the customization of the K4Care system.

The ATAPO tool has a wizard to help the user to personalize the ontology according to the rules defined by the medical partners of the project. This is very important in the medical field, because there are strict organizational norms defined that must be followed.

On the one hand, it restricts the customization to documents and actions. On the other hand, the ATAPO tool controls that the requests of the user fits on his role. For example, the user cannot ask for a reading permission of a document that already is available to him, or the user cannot request to make an action out of his competencies. After any request of modifications in a user's profile, the system controls that the corresponding physician in charge authorises the changes, before storing them in the user's subAPO.

The ATAPO tool is integrated into the K4Care system to have access to the same Knowledge Resources. In particular, ATAPO needs the information stored in these resources to perform the following actions:

1. To validate a user (login and password are checked with the Data Base).
2. To know the roles that a particular user can play in the system (for example, a person could be a Nurse and also a Continuous Care Provider or even a Patient). This is needed to make the role-centered control mentioned before, which is required to follow the organizational rules of this kind of medical systems.
3. To retrieve a subAPO of a user (if it exists) in order to know the current profile.

4. To store a subAPO that has been modified or recently created. In particular, each subAPO is registered in a Data Base that is used by the DAL to know which is the state of each user's profile, and the ontology file is stored into the system.

This last step is the most important, since it produces the personal ontology that can be used to dynamically adapt the behaviour of the system according to the new profile.

3.2. The multiagent system customization

The main benefit of the inclusion of the tailoring and personalization tools, where any user could use ATAPO to modify his/her personal profile, is that the K4Care system can use these personal ontologies instead of the general one to act accordingly. In the K4Care multi-agent system, each real-world actor is represented by a permanent agent. Those agents implement the functionalities of the corresponding user profile. They have all the information related to the current activities of its particular user. They also manage all the queries and requests coming from other agents. In the K4Care system, dynamic agents that adapt themselves to each user profile are proposed; the agents' behaviour rules are obtained from an ontology rather than being hand-coded.

Therefore, on the one hand, exploiting the organizational knowledge stored in the APO permits to automate the implementation of the personal agents. An especial module called *code generator* creates the basic software components needed to implement the agent functionalities according to the knowledge stored in the ontology [7]. However, the code generated only considers static structural elements of the Actor Profile Ontology, which are not affected by the personalization.

On the other hand, the agents automatically adapt their behaviour according to each particular user profile, which permits the customization of the system. At execution time, the subAPO is used to dynamically guide the execution of HC processes according to the personal profile of each particular actor and the structure of the medical organization. Remember that if a user has not created his/her subAPO, the general APO is used. There are three main functionalities that exploit this personalized knowledge:

1. To configure the interface. For example, in Figure 4, Mr. Kovac, a Family Doctor, can see the set of services that he can initiate, which is retrieved at runtime from the corresponding subAPO.
2. To establish the document permissions for each particular user when the results of a medical action must be reported, or when the user wants to read some documents available in the system. For instance, Mr. Benton, who customized his profile to have access to the Diagnosis and Decision Documents (Fig. 2), will see these documents also in the interface, together with the usual ones.
3. To start the execution of an individual intervention plan on a patient [7]. At this moment, the agents use the APO to know which is the procedure (i.e. set of actions) needed to provide a particular service (e.g. the provision of a medical treatment). Afterwards, the subAPOs are used by the intelligent agents to know the set of actors that are available to perform each of the actions of the procedure. With this information the Head Nurse has up-to-date information about the medical team and can distribute the work among them.

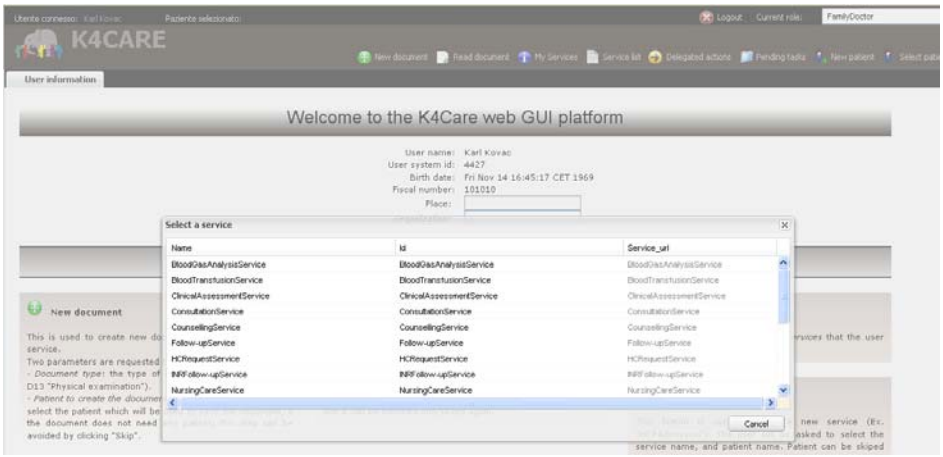

Figure 4. Services available to Dr. Kovac (K4Care web interface).

With this model, the Data Abstraction Layer always keeps track of the updated versions of the user's profiles. Consequently, the agents always receive the information regarding the latest personalization of the profiles. Therefore, the behaviour of the system is constantly synchronized with the user's requirements.

4. Conclusions

An approach to the customization of multi-agent systems by means of profile ontologies has been presented. In order to have a coherent model, it is needed to define a general reference ontology that describes the role of each actor type in the system. This ontology represents the structural knowledge of the organization that is modelled. Then, specific ontologies can be generated from this general one, following some constraints that permit to fulfil the basic organizational rules.

The main benefits of using an ontological representation over other data representation structures are that ontologies are specially designed to be machine readable, and that they provide several structures that can be exploited for inference reasoning (e.g. taxonomical and non-taxonomical relations, specific domain constraints, etc.).

The paper presents the design of a system that includes a personalization tool and a web-based system based on intelligent agents. The paper also explains how the agents use the customized ontologies to guide its behaviour.

The particular case of the K4Care system has been explained to illustrate how this process can be used for improving Home Care assistance. A prototype has been tested in a real environment, in the municipality of Pollenza (Italy) with the participation of healthcare professionals, caregivers and patients. The users evaluated different aspects of the K4Care system, in particular, technology acceptance. At the moment, we do not have the definite results of this evaluation, but the general impression is quite promising.

As it has been said, in the case of healthcare assistance, the possibility of personalizing the system, together with usability and security aspects, can play an important role in the acceptance and socialisation of this kind of software tools [14].

Moreover, from a technical point of view, combining a multi-agent system with ontologies is the key to guarantee adaptability of the system to future structural modifications of the model, either in short, mid or long term. On one hand, the ontology makes the system scalable and adaptable to new laws, norms or ways of doing. On the other hand, the possibility of managing multiple personal ontologies permits to capture the dynamics of the organization and adapt the system to different particular situations online.

Acknowledgements

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