An Intelligent Platform to Provide Home Care Services

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Abstract. The progressive increase in the percentage of old people in all European countries implies an enormous economic and social cost, which can be somehow reduced if *Home Care* services are improved. The *K4Care* European project is studying the feasibility of using Information and Communication Technologies to improve the management of Home Care. This paper details the project objectives, the *K4Care Home Care model*, and the declarative and procedural knowledge needed in Home Care. It also describes the architecture of the agent-based web-accessible *K4Care platform*, and how the intelligent agents coordinate their actions to provide the basic Home Care services defined in the model.

Keywords: Home Care, ICT, agent technology, ontologies, clinical guidelines

1 Introduction

In electronic Healthcare (*e*Health) it is increasingly necessary to develop computerised applications to support people involved in providing basic medical care (physicians, nurses, social workers) [13]. The care of chronic and disabled patients involves lifelong treatments under continuous expert supervision. Moreover, healthcare workers and patients often consider traditional treatments in hospitals or residential facilities unnecessary and counterproductive, in terms of time and efforts they have to spend. Such patients may also saturate national health services and increase health related costs. To face these challenges we need to differentiate medical assistance in health centres from assistance in a ubiquitous way (Home Care -HC- model); the latter can undoubtedly benefit from the introduction of Information and Communication Technologies (ICT) [9]. The *K4Care* project presented in this paper proposes an ICT-based model of HC in order to support the provision of care services to a patient that requires assistance at home. The typical *HC Patient* (HCP) is an elderly patient, with co-morbid conditions and diseases, cognitive and/or physical impairment, functional loss from multiple disabilities, and impaired self dependency. The healthcare of the HCP is particularly complex because of the growing number of patients in such circumstances, and also because of the great amount of resources required to guarantee a quality long-term assistance. The project is developing a platform to manage the information needed to guarantee an ICT Home Care service, which includes: an integration with ICT whilst ensuring private and customized data access; the use of ontologies to define the profile of accessing subjects; a mechanism to combine and refine the ontologies to personalise the system; the incorporation of *know-how* from geriatric clinical guidelines (known as *Formal Intervention Plans* [10] - IPs); the generation of FIPs from the personalised healthcare treatments; the configuration of a knowledge-based decision support tool that can supply *e*-Services to all subjects involved in the home care model; and finally, the extraction of evidence from real patients and its integration with published evidence derived from randomised clinical trials [8].

The present paper's content is structured as follows: the next section highlights the objectives of the *K4Care* project; section 3 is devoted to the *K4Care* model and its fundamental elements; section 4 clarifies the importance of the medical knowledge representation, while section 5 presents the *K4Care* architectural components. Conclusions and acknowledgements close the presentation of this paper.

2 *K4Care* Objectives

The achievement of the *K4Care* project's objectives involves different aspects. First of all, the project is capturing and integrating the information, skills, expertises, and experiences of specialised centres and health care professionals. These will be incorporated in an intelligent web platform to provide *e*-services to health professionals, patients, and citizens in general. Aside from this high level goal, more specific objectives can be classified as *general* or *technological*.

General objectives aim at generating a new ICT Sanitary Model (*K4Care model*) for assisting HCPs. The system will seamlessly integrate services, healthcare practices, and assistance knowledge coming from old and new European countries. Moreover a telematic and knowledge-based CS platform (*K4Care platform*) that implements the *K4Care* model will be proposed.

Technological objectives will provide a personalisation in the access to the *K4Care* platform, by adapting the knowledge to the user requirements in order to customize the assistance provided by the *K4Care* model. The personalisation in the assistance to senior citizens is a key point, considering that general purpose clinical guidelines, as they stand, are not valid in real practice since a HCP has a combination of features which makes his/her treatment different from any other treatment.

Finally, other technological objectives will conceive the design and implementation of intelligent agents that allow users to access the EHR, edit, adapt, and merge ontologies, and introduce and induce Formal Intervention Plans. The combination of these intelligent agents in a multi-agent system will provide *e*-services to care-givers, patients and citizens (*e.g.* scheduling of prolonged clinical treatments, intelligent decision support, and intelligent distribution of data among users).

3 Model

The *K4Care Model* defines the basic elements supported by the system and their relationships. In the model, services are distributed by local health units and integrated with the social services of municipalities, and eventually with other organizations of care or social support. The model is aimed at providing the patient with the necessary sanitary and social support to be treated at home. To accomplish this duty, the *K4Care model* gives priority to the support of the HCP, his/her relatives and Family Doctors (FD) as well. Because of its aim, the model is represented by a *modular structure* that can be adapted to different local opportunities and needs. The success of this model is directly related to the levels of *efficacy, effectiveness* and *best practice* of the healthcare services the model is able to support.

Basically, the *K4Care Model* is based on a *nuclear structure* (HCNS) which comprises the minimum number of common elements needed to provide a basic HC service. The HCNS can be extended with an optional number of *accessory services* (HCAS) which will respond to specialized cares, specific needs, opportunities, means, etc. The distinction between the HCNS and the complementary HCASs should be interpreted as a way of introducing flexibility and adaptability in the K4Care model. In more detail, each one of the HC structures (*i.e.* HCNS and HCASs) has the same components: a) *Actors* are all the sort of human figures included in the HC structure; b) *Professional Actions and Liabilities* define the tasks that each actor performs to provide a service within the HC structure; c) *Services* provided by the HC structure for the care of the HCP; d) *Procedures* are the chains of events that lead an actor in performing actions to provide services; and e) *Information* contained in *documents* required and produced by the actors to provide services in the HC structure.

As new HCASs are incorporated to the *K4Care Model*, new actors, actions, services, procedures and information enter to be part of the extended model. In this way, the *K4Care model* is compatible both with the current situation in the European countries where the international, national, and regional laws define different HC systems for different countries, and also with the forthcoming expected situation in which a European model for HC will be decided.

3.1 Actors

In HC there are several people interacting: patients, relatives, physicians, social assistants, nurses, rehabilitation professionals, informal care givers, citizens, social organisms, etc. These individuals are the members of three different *groups of HC actors*: a) the *patient*; b) the *stable members* of HCNS (the family doctor, the physician in charge of HC, the head nurse, the nurse, and the social worker); and 3) the *additional care givers* (see Fig. 1).

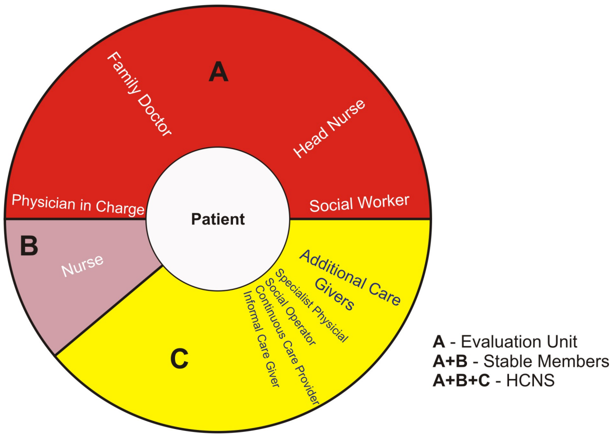

Fig. 1. Actors in the Home Care Nuclear Structure (HCNS).

The family doctor, the physician in charge of HC, the head nurse, and the social worker join in a temporary structure – the *Evaluation Unit* – devoted to assess the patient's problems and needs, to decide the treatment (by constructing the *Individual Intervention Plan* – IIP – based on one or more Formal Intervention Plans) and to monitor its progress. The patient is located in the centre of the HCNS of the *K4Care model* (see Fig. 1), and the rest of the groups are organised around it as a symbol of a patient-oriented HC model.

3.2 Professional Actions and Liabilities

These represent general actions that each one of the actors in the *K4Care model* performs in his/her duties within the HCNS. Two lists of actions are provided for each sort of actor: the list of general actions, and the list of HCNS actions. The list of general actions is intended to contain all the actions that actors are expected to perform in a general purpose Home Care System. The list of HCNS actions complements the explanation with the specific actions the *K4Care Model* defines for the actors involved in the HCNS. Any action represents a professional activity for which the actor is liable.

3.3 Services and Procedures

The HCNS provides a set of services for the care of HCP. These services are classified in *Access services*, *Patient Care services*, and *Information services*. *Access services* see the actors of the HCNS as elements of the *K4Care model* and they address issues like patient admission and discharge from the HC model. *Patient Care services* are the most complex services of the HC model as they consider all the levels of patient care as part of the HCNS. Finally, *Information services* cover the needs of information that the HCNS actors require in the *K4Care model*. Examples of very relevant services are: the *Comprehensive Assessment* (which is the service devoted to detect the whole series of HCP diseases, conditions, and difficulties, from both the medical and social perspectives), the *Intervention Plan Definition* (which represents the course of actions to be performed in order to provide care to the HCP in terms of treatment and support) and the *Intervention Plan Performance* (which defines the execution of a previously defined IP). In the *K4Care Model* a *procedure* represents the way that the actions provided by/to the actors are combined to accomplish one service.

3.4 Information Documents

The HCNS structure defines a set of information units whose main purpose is to provide information about the care processes realised by the actors to accomplish a service. Different kinds of actors will be supplied with specific information that will help them to carry out their duties in the *K4Care model*. All these data are considered here to be part of specific *documents* and used through services and procedures. For that relation, documents are also classified in *documents in Access services*, *documents in Patient Care services*, and finally, *documents in Information services*. The first set of documents stores the information required in each one of the *K4Care* access services. The documents in the next set are the most complex since they may have different general purposes inside the sets of services and procedures. They can be subdivided into request documents, authorisation documents, prescription documents, and anamnestic documents. The last kind of documents, related to information services, usually report underlying activities but also represent officially recognised information related to HC, and are shared among different actors across the HC life cycle.

4 Medical Knowledge Representation

There are two kinds of knowledge to be represented in the system: *declarative* and *procedural*. The former contains the information on the basic elements of the *K4Care model* and the organisational relationships between the system actors. The later is concerned with the representation of the sequences of actions involved in the provision of a service or the treatment of a patient. Apart from all this knowledge, all data concerning patients are stored in the Electronic Health Record, which is consulted by actors as needed in the different stages of the patients' treatment.

4.1 Declarative Knowledge

Ontologies, as a set of concepts, properties and relations, constitute a feasible paradigm to represent the declarative knowledge used in the system [3,5]. There are two basic ontologies in *K4Care*, which have been defined *ad hoc* for this project. The first ontology, named *Actor Profile Ontology* (APO), details the basic elements of the *K4Care HC model* (actors, actions, services, procedures, documents) and the relationships between them (*e.g.* which actions may be performed by each kind of actor, or which document is associated to each action). The second one, named *Case Profile Ontology* (CPO), stores all the medical terms related to HC (diseases, syndroms, signs, symptoms, assessment tests, clinical interventions, laboratory analysis, social issues) and the relationships between them (*e.g.* the diseases included in a certain syndrom, or the symptoms of a disease). Agents will be able to reason using the knowledge contained in this ontology, which can be considered as a bridge between the concepts that agents are able to recognize (conditions, diseases) and how actors have to act on those situations (associated interventions). Taxonomic and non taxonomic relations between concepts have been defined in order to allow structuring the information in an appropriate way to answer high level queries about that data.

4.2 Procedural Knowledge

On the other side, *procedural* knowledge that codifies complex medical tasks is required to define the set of available actions performed by all actors in the platform [1]. Medical experts defined a set of procedures related to chronic diseases that are stored and managed by actors. That knowledge is coded using a flowchart-based representation called SDA* [6]. The basic elements of SDA* structures are *states*, *decisions* and *actions*. *States* describe patient condition situations. *Decisions* code alternative options required to guide the enactment of a plan. An *action* is one of the activities that an actor can perform in the treatment of a patient. Between those elements, directed edges define the direction of the steps and can be labelled with temporal constraints. The SDA* formalism is used in *K4Care* to represent three kinds of elements:

- *Procedures*: descriptions of the steps to be taken within the *K4Care platform* to provide one of the HC services.
- *Formal Intervention Plans (FIPs)*: general descriptions defined by healthcare organisations such as the National Guideline Clearinghouse ([10]) used to represent health care procedures to assist patients suffering from one or several ailments or diseases.
- *Individual Intervention Plans (IIPs)*: descriptions of the specific treatment that has to be provided to a particular patient.

When a patient is added to the system, his/her physical, clinical and social states are assessed by an Evaluation Unit. The diseases and syndroms of the patient are identified, and the FIPs associated to each of them are retrieved from a repository. This set of FIPs is merged, to get a single Formal Intervention Plan appropriate to deal with all the problems of the patient. Finally, this FIP is turned into an *Indivdual Intervention Plan* (IIP) by *tailoring* it to the specific personal circumstances of the patient. After that, the intelligent agents in the *K4Care platform*, as will be seen in the next section, have to coordinate their activities to execute the different steps of the IIP to provide the care to the patient.

5 *K4Care* Architecture

The architecture of the *K4Care* system is divided in three main modules: the *Knowledge Layer*, the *Data Abstraction Layer*, and the *K4Care agent-based platform* (see fig. below).

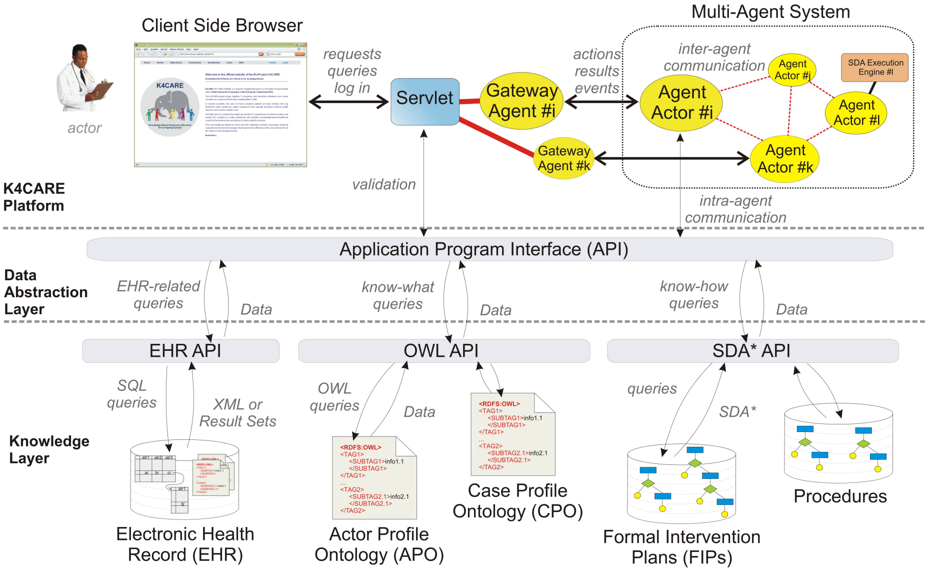

Fig. 2. K4CARE Architecture

The *Knowledge Layer* includes all data sources required by the platform. It contains an *Electronic Health Record* that stores patient records (personal information, medical visits and ongoing treatments). The procedural -organisational and medical-knowledge (know-what) is represented in the APO and CPO ontologies, using OWL. Medical procedures (that implement services) and Formal Intervention Plans are coded using the flowchart-like representation SDA* and stored in specific databases.

The *Data Abstraction Layer* provides some Java-based methods that allow the *K4Care* platform entities to retrieve the data and knowledge they need to perform their tasks. That layer offers a wide set of high level queries that provide transparency between the data (knowledge) and its use (platform) [1].

The *K4Care platform* is a web-based application with a client and a server side. Any actor (*e.g.* physician in charge, nurse, patient) interacts with the system through a web browser and is represented in the system by a permanent agent (*Agent Actors* in Fig. 2) that knows all details about his/her roles, permissions, pending results, pending actions, and that manages all queries and requests coming from the user or other agents. In order to exchange information between the agents and the actors there is an intermediate bridge constituted by a servlet and a *Gateway Agent* (GA). The servlet is connected with the browser user session. It creates a GA each time that an actor logs in the system, whose mission is to keep a one-to-one connection with the corresponding permanent agent.

The agent-based module embeds all the system logic. Agents act semi-automatically, in the sense that several actions such as exchange of information, collection of heterogeneous data concerning a patient (results, current treatment, next recommended step, past history), or the negotiation of a medical visit can be performed by the agent without the intervention of the user. Of course, other actions such as the confirmation of the formation of an evaluation team or the evaluation of some result received from a laboratory require the user validation. Basically the multi-agent system is composed by *actor agents,* that represent practitioners and patients, that use the Data Abstraction Layer methods in order to access to the data, one *servlet* and several *gateway agents* that allow to exchange information between the MAS and a web-based application, and finally a *SDA* execution engine agent* that allows to enact a procedure for a patient and recommend the next action to follow according to his/her current state.

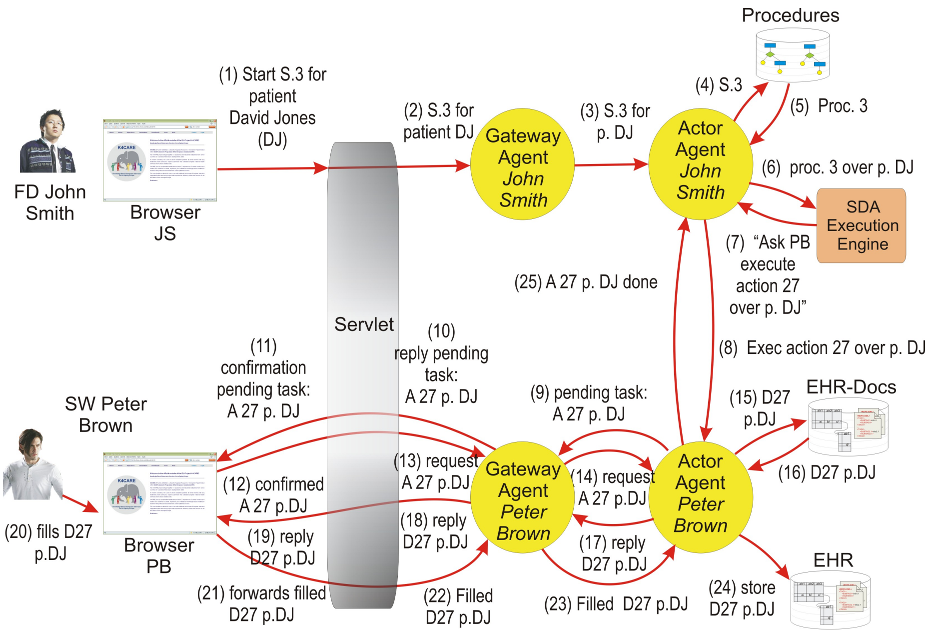

Fig. 3. Coordination among agents during service management

Let us shortly describe how a service is executed by the agents. Fig. 3 shows the dataflow involved in the provision of a service. Imagine that the Family Doctor John Smith logs into the system and requests service *S.3* for the patient David Jones (DJ) (step 1). That request is received by the servlet that creates the corresponding *Gateway Agent* (GA) for John Smith in order to interact with his *Actor Agent* (steps 2-3). The John Smith agent retrieves the appropriate procedure for service *S.3*, and forwards it to the *SDA Execution Engine* (SDA EE) (steps 4-6). The SDA collects all needed data of the patient in order to enact it. At a certain step of the procedure, the

SDA EE could recommend executing the action “A 27” over the patient, and that action is made by a Social Worker. Then, the John Smith agent should look for an agent that could perform that action. In that case, the Social Worker called Peter Brown is able to perform this task (step 8). The Peter Brown’s agent receives the request to make action “A 27” on David Jones, and stores it (steps 9-11). When Peter Brown logs into the system, the system through his agent summarises all pending actions (e.g. received results, incoming requests). After selecting the pending action on Mr. Jones (steps 12-14), his actor agent retrieves the document to be filled in action “A 27” from the repository (steps 15 and 16). That document is forwarded to the social worker -through its agent, gateway agent, servlet- (steps 17-19) and is finally shown in the browser. After filling the document, all the data is stored in the EHR of the patient and it can be collected in the next step by John Smith (steps 20-24).

6 Related work

The project covers two main medical topics: *enactment of medical procedures* using agents, and representation of medical knowledge with *ontologies*. Several projects such as GLARE, DeGeL, SAGE, Arezzo™, GLEE, and NewGuide allow enacting clinical guidelines coded using different representations in order to analyse the steps followed by a patient during a treatment [2,4]. All these tools have a repository of guidelines and an EHR, but they are not designed to be an open platform of services to be used by practitioners and patients. On the other hand, the use of ontologies in the medical domain has been shown to provide important advantages. Researchers have to study which classes, properties and relations could be the most adequate in a certain medical area, and also how these ontologies could be used in the daily work. Kumar *et. al.* use the ontologies to represent clinical guidelines [7]. Sánchez and Moreno learn ontologies (classes and relations) from the web [11], and Serban *et. al.* use the ontologies to extract medical patterns contained in textual clinical guidelines [12].

7 Conclusions, future work and acknowledgements

The paper explains the main ideas of the ongoing EU-funded *K4Care* project. The *K4Care model* was designed to carry out some care services provided to a patient that requires assistance at home. In addition, the model has a generic structure easily adoptable in any of the EU countries. Actors, services, procedures, and all kind of required data have been introduced in order to explain the knowledge representation and the proposed architecture.

We are currently working on the methodology to derive the code of the agents of the execution platform from the domain knowledge in order to automate the creation of personalised agents according to the actors profile. The SDA EE and the tools to access the ontologies have been already implemented and tested. Now, the inter-agent communication is being developed as well as the communication MAS-browser through the servlet and the *Gateway Agents*.

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