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How to facilitate the connection between distributed data and agents in the K4Care project.

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1 INTRODUCTION

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. The number of this type of patients is growing in the first world societies. In addition, it is required a great amount of resources to guarantee a quality long-term assistance. These are the two main reasons that make the healthcare of Health Care Patients (HCP) complex and difficult to manage.

K4Care is an ehealth project that tries to solve one of the main social problems in our society: the care of senior citizens and chronically disabled persons. This sector of the population is characterized by the need of complex and expensive treatments, which is a problem that requires a lot of efforts to be solved. There is a general agreement among the experts in the field that the solution must necessarily pass through de-centralizing services, especially supporting homecare actions. However, current healthcare infrastructures in European countries are still not completely prepared for this change.

The European project K4CARE: “Knowledge-Based Homecare eServices for an Ageing Europe“ will develop a distributed platform to improve the capabilities of the new EU society to manage a personalized Home Care assistance of the increasing number of senior population.

1.1 Motivation and objective

The main two objectives of K4Care project are: (1) to create a sanitary model at European Level for the care of senior patients that suffer chronic diseases or are disabled and need a treatment; and (2) to design and implement an Information and Communication Technology (ICT) platform that supports this model. With respect to the first goal, it is tried to unify the way in which medical centres of different countries work, so that the exchange of information between centres will become easier, as well as the transfer of the patients from one place to another. With respect to the second goal, a Multi-Agent System [32] that supports the different kinds of people involved in home care treatment (physicians, nurses, patients, etc.) will be implemented. In this system, patients and professionals should be able to access anytime and anywhere to all the necessary health information (x-rays, analysis, prescriptions, etc.) in an integrated way.

In this context, the agents of the system will need to access the sanitary model defined in the K4Care project and to the data related to the patients, such as treatments, prescriptions or information about their health. These data, or K4Care knowledge, are distributed in different sources and encoded in different formats (for example, health information about the patients is in XML documents and diseases are defined in ontology). This multiple language representation makes the communication between the agents and the information system difficult. In addition, patient’s attention is done following concrete medical procedures. In the initial version of the K4Care model, these procedures did not have a formal representation.

My work in this project is related with different parts of the K4Care:

- The study of the different Electronic Health Record standards and Electronic Health Record in K4Care.
- The design of an intermediate layer that helps to manage the communication, which is called Data Abstraction Layer. This layer plays an integrating role between the Multi-Agent System and the knowledge sources. This layer is in charge of providing the data that the agents need for the management of the sanitary model and allows to obtain and to store data in a transparent manner to the final localization and format in which the information is stored.
- A formal representation for procedures in K4Care.

In the following sections we will explain the process that leads us to design the Data Abstraction Layer. A real example extracted from the K4CARE project will be used to illustrate the construction of this intermediate layer and its use of the knowledge. This document is organized as follow: in section 2 we will give the K4Care project description and we will explain its objectives. In addition, the first version of the K4Care model is presented; in section 3 we will explain the data sources in the K4Care; in section 4 it is shown how the procedures that represent services should be encoded; in section 5 we present a case study to explain in detail the Data Abstraction Layer; in section 6 describes the new layer incorporated to the model, the Data Abstraction Layer and we can find the definition of Data Access component of the Data Abstraction Layer; in section 7 there are explained the contributions to the project, and the publications done; finally, in section 8 we present some conclusions and future work.

PART I: CONTEXT DESCRIPTION

2 THE K4CARE PROJECT DESCRIPTION

2.1 Introduction to the K4Care project

In eHealth it is increasingly necessary to develop tele-informatic applications to support people involved in providing basic medical care (physicians, nurses, patients, relatives, and citizens in general).

The care of chronic and disabled patients involves life long treatment under continuous expert supervision. Moreover, healthcare workers and patients accept that being cared for in hospitals or residential facilities may be unnecessary and even counterproductive. From a global view, such patients may saturate national health services and increase health related costs.

The K4Care project will develop a platform to manage the information needed to guarantee an ICT (Information and Communication Technology) Home Care service. It will:

- a) integrate information of different types and from different sources.
- b) be integrated with ICT whilst ensuring private and customized data access.
- c) use ontologies to define the profile of accessing subjects (e.g. physicians, patient) and objects (e.g. disease, case study).
- d) have a mechanism to combine and refine the ontologies to personalize the system, taking into account the way a physician works and the individual patient characteristics.
- e) incorporate 'know-how' from geriatric clinical guidelines as Intervention Plans (IP).
- f) generate IPs from the healthcare centres databases if clinical guidelines do not exist or are inappropriate for a particular situation.
- g) configure a knowledge-based decision support tool that can supply eServices to all subjects involved in the Home Care model.
- h) extract evidence from real patients and integrate it with published evidence derived from RCTs.

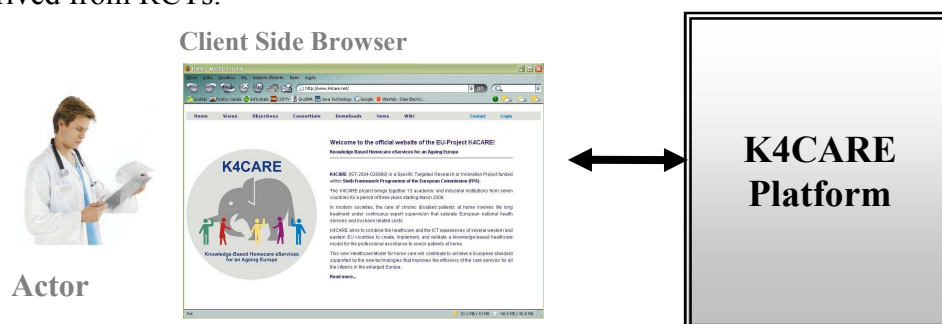


Figure 1 K4Care

In this chapter we first make a description of the K4Care project, explaining the general goals, the participants and workpackages. Then we detail which is the work of the URV team and my work. Then, we describe the K4Care model that has been defined until now and which is the one that we will use in this master thesis.

2.2 Objectives of the K4Care project

The K4Care system intends to impact in two societal aspects: (1) contributing towards an European healthcare convergence, and (2) increasing the quality of life of homecare Health Care Patients (HCPs).

The main objective of the K4Care project is 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 Health Care (HC) assistance. The project will capture and integrate the information, skills, expertise, and experiences of specialised centres and professionals of several EU countries, and will incorporate them in an intelligent web platform in order to provide e-services to health professionals, patients, and citizens in general.

General objectives

- O1. Generate a **new ICT Sanitary Model (K4Care model)** for assisting HCPs in the enlarged Europe. The system will seamlessly integrate services, healthcare practices, and assistance knowledge coming from old (e.g. Italy, UK) and new (e.g. Czech Republic, Romania, Hungary) European countries.
- O2. Propose a **telematic and knowledge-based CS platform (K4Care platform)** that implements the above model. This platform will include all the technologies developed in the project and it will assist all the human actors involved in the care of HCPs. These actors include physicians, nurses, social workers, rehabilitative professionals, patient relatives, patients themselves, and citizens in general.
- O3. The platform will be tested on west (Italy, UK) and east (Czech Rep., Romania, Hungary) EU societies through pilot tests in order to highlight their differences and also to pursue a convergence to a homogeneous way-of-doing, contributing to a unique European Healthcare ICT society in HC.
- O4. The K4Care platform can serve as a means of integrating knowledge about HCPs assistance all over the new and old EU countries. Some healthcare centres from Italy, UK, Czech Republic, Romania and Hungary will work to demonstrate that sharing this sort of knowledge across EU countries is not only possible but also beneficial and necessary for achieving an **European standard HC service supported by the new technologies**.

Scientific Objectives (Integrating information)

- O5. The project will define a solution for Electronic Health Record (EHR) incorporating lessons learned in past experiences (e.g. I4C/TripleC, PROREC and Provenance projects), and exploiting the knowledge of the consortium about standards within this field. The defined EHR will be implemented and used to store information about HC. This EHR will **integrate different data types (e.g. text, numerical values, multimedia parts) and documents coming from different sources (e.g. hospital services, laboratories, consultations, specialists, relatives and patients at home)**.
- O6. Within the project, the cooperating healthcare partners will pre-process information about physicians, patients, citizens and other agents involved in the K4Care model and will fill in the EHR with it in order to have a test bench with real data. The EHR

will **integrate information coming from different EU member countries** (homogenising the differences) and will be under continuous evaluation and adaptation deriving from the specialised partners indications.

Scientific Objectives (Knowledge representation)

O7. Define the *Actor Profile Ontologies* (APO) for representing the profiles of the subjects involved in the K4Care model: healthcare professionals, patients and relatives, citizens, and social organisms.

APOs contain the **skills, concerns, aspirations, etc. of the people** that they represent, together with the **healthcare services** that those people offer to or receive from the K4Care model (e.g. *medical services* such as drug prescription, clinical consultations, laboratory analysis; *social services* such as counselling, information, advice, social support).

O8. Define the *patient-Case Profile Ontologies* (CPO) for representing symptoms, diseases, syndromes, case mix. APOs and CPOs describe "**know-what**" knowledge about agents accessing the K4Care model, and "pure" pathologies the K4Care model gives support to, respectively. These ontologies are based on terms related to symptoms, signs, drugs, medical and surgical procedures, dietetic conditions, physical and hygienic requirements, cognitive functions, self-dependency, etc.

O9. Define *Formal Intervention Plans* (FIP) for a number of disease and syndrome treatments. These FIPs will be generated from the information deriving from the available evidence-based clinical practice guidelines that represent standards of practice, particularly in the fields of geriatrics. These FIPs represent the professional worldwide existing "**know-how**" knowledge within the K4Care platform, and they will guide the services the system offers to the professional users. In other word

Technological Objectives (Knowledge adaptation and use)

O10. **Personalise the access to the K4Care platform.** Adapt the APOs to the user requirements in order to **customize the access to the EHR and the assistance provided** by the K4Care model, because not all the patients wish their care in the same way (in terms of services, treatment, explanation, terminology, etc.). The developed personalising methods will also be applied to the care-givers ontologies in order to represent the fact that not all the professionals interact with the healthcare system in the same way. The particularized ontologies and the interface technologies, together with **usability and security** aspects, will play a crucial role in the acceptance and socialization of the K4Care platform.

O11. **Personalise the assistance to senior citizens.** CPOs 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. Developed technologies for merging prototypic CPOs will be used to have CPOs adjusted to the individual condition of the patient.

O12. FIPs will be inductively learned from the EHR with the use of new machine learning techniques. These techniques must be developed and tested in the domain of HCPs. They are learned from the procedures regarding past patients stored in the system.

Technological Objectives (Service Supplying)

- O13. Design and implement **intelligent agents** that allow users to access the EHR, edit, adapt, and merge ontologies, and introduce and induce FIPs. Combine these intelligent agents in a **multi-agent system** that provides 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). Deliver those services through the Internet and the mobile telephony in a safe, everywhere, anytime way.
- O14. Develop an application that will be integrated in the K4Care platform for **localizing patients topographically**. This is particularly relevant for some sort of patients with memory or cognitive impairments and also in order to anticipate the medical and care actions.

2.3 Participant list

Different types of communities will work together in this project. On the one hand, the consortium has universities (URV, CVUT and UNIPG) and research institutes (MTA-SZTAKI). On the other hand, there are hospitals and other healthcare organizations with healthcare professionals and patients (CAD, ANA, FSL, GUH and SJH) and a town council in contact with the population (i.e. citizens) of an Italian region (COMPOL). Moreover, a large company will give support to the deployment of the IT technologies for the project (TI) and a SME will be in charge of the management aspect of the project (EURICE).

Participant no.	Participant name	Participant org. short name
1 (coord)	Universitat Rovira i Virgili	URV
2	Centro Assistenza Domiciliare Azienda Sanitaria Locale RM B	CAD
3	Czech Technical University in Prague	CVUT
4	University of Perugia	UNIPG
5	Telecom Italia S.p.A.	TI
6	European Research and Project Office GmbH	EURICE
7	Ana Aslan International Academy of Aging	ANA
8	Fondazione Santa Lucia	FSL
9	Computer and Automation Research Institute of the Hungarian Academy of Sciences	MTA SZTAKI
10	The Research Institute for the Care of the Elderly	RICE
11	Amministrazione Comunale di Pollenza	COMPOL
12	General University Hospital in Prague	GUH
13	Szent Janos Hospital	SJH

Table 1. List of participants

2.4 Work packages

The K4Care project is divided into the following nine work packages. The objectives of each package and the work load of each participant can be seen in the definition of the packages.

WP01: Define the K4CARE Model

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
2,5	9,0	1,0	7,0	3,0	0,0	6,0	3,5	0,0	3,0	0,5	2,0	2,0

Objectives

- Define the actors involved in a ICT sanitary model for assisting HCPs in an enlarging Europe, integrating the skills, expertise, and experiences of old and new EU countries.
- Identify the functionality of such model, the intelligent services, and the new technologies required to approach such model to the reality of the health professionals, the patients, the care givers, and the citizens in general.

WP02: Develop the Electronic Health Record

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
1,5	4,0	25,0	3,0	3,0	0,0	3,5	0,5	15,0	3,0	2,0	3,0	3,0

Objectives

- Develop the information system structures to support the data level of the K4C platform. Generate an Electronic Health Record (EHR) specific for the healthcare domain of the project. This EHR must integrate different data types about patients, diseases, and health professionals and be ready to seamlessly accept multilingual assertions. Developing such data structures observing the EU standards (CEN/TC251 at <http://www.centc251.org>) on data security (ENV 12251 and ENV 13608) and data representation (ENV 13606) is mandatory for the interaction of the system with other computer-based healthcare systems. A XML schema (or DTD) of the database will be available in order to permit the exportation of portions of data in the EHR to XML files.
- Fill in the above structures with real data that will act as a test set for the developed technologies.

WP03: Develop the K4CARE Domain Ontologies

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
12,0	13,5	11,0	17,5	0,0	0,0	4,5	1,5	3,0	5,0	1,5	1,0	1,0

Objectives

- Propose a set of ontologies representing an abstraction of the profiles of the actors involved in the process: It will be defined a K4Care actor profile ontology. The actor profile ontologies (APO) will represent prototypes of healthcare professionals, patients and relatives, citizens and social organisms in a hierarchical structure
- Supply a set of ontologies representing common pathologies of the sort of patients considered in the project: It will be defined a K4Care case profile ontology. K4Care case profile ontologies (CPO) represent the pathologies of the sort of patients the K4C model deals with (e.g. post-stroke patients, diabetics, cognitively impaired, mobility impaired). Among other concepts, these ontologies include conditions and diseases, medical case descriptions, and references to Formal Intervention Plans (WP04) representing healthcare guidelines for assisting those patients.

WP04: Develop K4CARE Formal Intervention Plans

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
34,0	30,0	5,0	15,0	0,0	0,0	6,0	2,5	0,0	1,0	0,0	1,0	1,0

Objectives

- Develop a family of Formal Intervention Plans (FIP) representing procedural knowledge about the treatments of the diseases identified in WP03.
- Adapt the FIP to the particularities of a patient to obtain an Individual Intervention Plan (IIP).

WP05: Implement Tools for Knowledge Tailoring

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
27,0	10,0	13,0	0,0	0,0	0,0	0,0	0,0	8,5	1,5	0,0	0,0	0,0

Objectives

- Develop computer tools for instantiating Actor Profile Ontologies (APO). An APO must be instantiated in a particular physician, patient or citizen before it is applicable. This instantiation process will permit that a particular actor could introduce his or her particular vision of his role in the K4C model.
- Develop computer-based tools for merging Case Profile Ontologies (CPO) in co-morbid patient models. The pathology of the patients use to be more complex due to the health particularities of the patient and also to the coexistence of several simultaneous conditions and diseases (comorbidities) which affect one each other.
- Develop computer management tools for personalizing FIPs. Several FIPs representing single treatments into one FIP describing a complex treatment.

WP06: Develop the K4CARE Platform

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
15,0	0,0	35,0	0,0	23,0	0,0	0,0	0,0	31,0	0,0	0,5	0,0	0,0

Objectives

The objective of this workpackage is to build a fail proof agent-based platform that will provide the basic functionalities of the K4C model. It will take into account the results of WP01 (types of users and system functionality), WP02 (content of the Electronic Care Record), WP03 (user and pathology profiles) and WP04 (content of a Formal Intervention Plan).

WP07: Evaluate, Assess and Apply the K4CARE Platform

Activity Type: Demonstration activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
1,0	14,0	0,5	8,5	9,0	0,0	4,5	3,0	0,0	3,0	5,0	3,0	3,0

Objectives

- Test the adherence of K4C platform to the needs and duties of home care providers, patients, citizens.
- Test the possibility of use of FIPs.
- Integrate EU knowledge in order to provide a homogeneous way-of-doing in the area of interest.
- Apply the K4C platform in a community to assess and evaluate the conditions of use.

WP08: Dissemination

Activity Type: RTD/Innovation activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
4,0	2,5	2,5	1,5	3,0	5,0	1,0	0,5	1,0	0,5	3,0	1,0	0,5

Objectives

To present the project objectives, activities and results to different target groups (professionals, decision makers, potential users, general public) and ensure widest possible take-up and exploitation of the project results in technological and healthcare areas.

WP09: Project Management & Administration

Activity Type: Management activities

Participant id and Person-months per participant:												
URV	CAD	CVUT	UNIPG	TI	EURICE	ANA	FSL	MTA SZTAKI	RICE	COMPOL	GUH	SJH
13,0	9,0	8,0	2,0	1,5	12,0	1,0	0,5	1,5	1,0	0,0	0,0	0,0

Objectives

The purpose of this work package is to monitor and co-ordinate all the project activities and ensure conformance with the project and quality plans. The general purpose of the project management are progress control of each work package, coordination of the different project activities, and implementation of quality control mechanisms by issuing appropriate project standards. Project management will cover financial, administrative, scientific as well as knowledge and innovation aspects.

2.5 Participation of the URV in the K4Care Project

The participation of URV in the K4Care project is distributed in the different work packages.

URV has collaborated in the definition of the K4Care sanitary model (WP01). The K4Care model defines the actors in the sanitary model (physicians, social assistants, nurses, rehabilitation professionals, relatives, informal care givers, citizens, social organisms, etc.) for assisting HCPs and their roles and integration. For example, it has, also, defined the functionality of the model, and the new technologies and intelligent services to make the system closer to the actors, easier to be used and more profitable determined. We will explain this in detail later.

In addition, URV has collaborated in the generation of an EHR specific for the healthcare domain of the project (WP02). A study became of the different EHR standards. Observing the EHR standards (CEN/TC251, HL7, DICOM, etc.) on data security and data representation is mandatory for the interaction of the system with other computer-based healthcare systems.

URV, also, works in the definition of the ontologies (the Actor Profile Ontology and the Case Profile Ontology) (WP03) and develops a family of Formal Intervention Plans (WP04) representing procedural knowledge about the treatments of the diseases identified in the definition of the ontology. It develops computer tools for instantiating Actor Profile Ontologies, and for merging Case Profile Ontologies in co-morbid patient models, and computer management tools for personalizing Formal Intervention Plans (WP05). Furthermore, URV participates in the development of an agent based platform to provide the basic functionalities of the K4Care model (WP06).

We will evaluate and apply the K4Care project, testing if the needs of K4C platform are correct for home care providers, patients and citizens, testing the use of FIPs, integrating EU knowledge in order to provide a homogeneous way-of-doing, and applying the K4Care platform in a community to assess and evaluate the conditions of use (WP07). In addition, it will participate in a dissemination task to present the project objectives, activities and results to different target groups (professionals, decision makers, potential users, general public) (WP08).

Finally, URV is in charge of the project management (WP09). URV coordinates the project controlling the progress of each work package.

My work in the project is located mainly into *WP02*, *WP01* and *WP06*. My contribution to WP02 was to do a study of the different EHR standards (HL7, CEN EN 13606, openEHR, etc.) and the elaboration of a survey of those standards [1]. I have also contributed proposing improvements in the Electronic Health Records and the data base. My contributions to WP01 and WP06 have been to propose an extension of the K4Care model. It was detected that the communication between the agents and the information system was difficult and inefficient because agents had to be able to

manage data from different sources using different languages. Finally, my proposal of a procedure representation is also in the scope of WP01.

2.6 K4Care model

In different European Countries, and in different areas of the same countries, health care is structured in different ways, according to local rules, laws, and funding. The K4Care model provides a paradigm easily adoptable in any of the EU countries to project an efficient model of health care.

The model proposes that the K4Care services are distributed by local health units and integrated with the social services of municipalities, and eventual other organizations of care or social support. It is aimed at providing the patient with the necessary sanitary and social support to be treated at home.

Because of the aim of providing a model which can be proposed as European standard, the K4Care project recommends 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 health-care services the model is able to support.

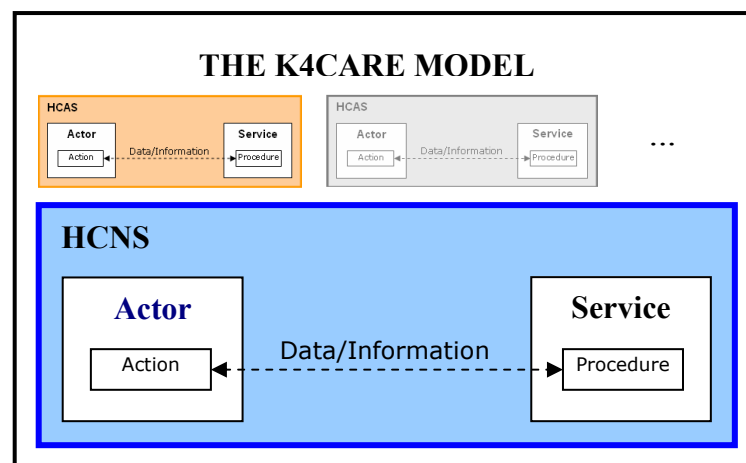


Figure 2. The K4CARE Model Architecture for HC

As shown in Figure 2 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)* that can be modularly added to the nuclear structure. These services will respond to specialized cares, specific needs, opportunities, means, etc. of either the users of the K4Care model or the health-care community where the model is applied.

The distinction between the HCNS and the complementary HCASs must be interpreted as a way of introducing flexibility and adaptability in the K4Care model and also as an attempt to provide practical suggestions for standards to be used when projecting and realizing new services in largely different contexts.

Going into detail, each one of the HC structures (i.e. HCNS and HCAS's) consists of the same components: **actors, actions, services, procedures, and documents**.

- *Actors* are all the sort of human figures included in the structure of HC.
- *Professional Actions and Liabilities* are the actions each *actor* performs to provide a *service* within the HC structure.
- *Services* are all the utilities provided by the HC structure for the care of the HCP.
- *Procedures* are the chain of events that leads an *actor* in performing actions to provide *services*.
- *Information* are the *documents* required and produced by the *actors* to provide services in the HC structure.

As new HCAS's are incorporated to the K4Care Model, new actors, actions, services, procedures and information enter to be part of the extended model.

2.6.1 Actors in K4Care

In health care there are several people interacting: patients, relatives, physicians, social organisms, etc. In the HCNS, these individuals are the members of three different **groups of HC actors**. In K4Care model this people are organized in three groups of actors: **patients, stable members**, and **additional care givers**. Figure 3 shows the patient (i.e. the HCP) in the centre of the HCNS of the K4CARE model, and the rest of the groups organised around it as a symbol of a patient-oriented HC model.

- **Patient (HCP)**: The average patient is an elderly patient, with co-morbid conditions and diseases, cognitive and/or physical impairment, functional loss from multiple disabilities, and impaired self-dependency.
- **Stable Members**: Represent professional actors.
 - **Family Doctor (FD)**: The FD is the physician who is in charge of the patient. FD diagnoses and treats the diseases, physiological disorders and injuries of patients. He provides primary contact and continuous care toward the management of patients' health.
 - **Physician in Charge of the HC (PC)**: The PC is a supervisor in the Evaluation Unit and the medical responsible of the HC service.
 - **Head Nurse (HN)**: The HN mainly coordinates the work of the nurses to accomplish the intervention plan.
 - **Social Worker (SW)**: The SW identifies and evaluates social needs, manages the social implication of the intervention plan and starts up social services, coaches the patient's social network organizing the empowerment of skills and resources of his formal and informal care providers.
 - **Nurse (Nu)**: The Nu is the provider of therapeutic procedures. Nu works at patient's home according to scheduled access.
- **Additional Care Givers (ACG)**: Represent other groups of professionals and non professional actors that are usually part of the health care. These groups of Additional Care Givers do not have an exact and definite position in the context of

the health care network, but their role results, in most case, fundamental for the continuous care of the HCP.

- **Specialist Physician (SP).** The SP is a medical doctor specialized in one branch of medicine.
 - **Social Operator (SO).** The SO represents the operative branch to support social needs of the HCP directly at home, with special regard to ADLs and IADLs.
 - **Continuous Care Provider (CCP).** The CCP is the actor who is in charge of the continuous care of the HCP, usually 24 hours a day. CCP can be, in different cases, a relative or a third person on salary.
 - **Informal Care Giver (ICG).** The ICG is a person who provides the HCP with a more or less relevant amount of support, not being tied by professional or familiar relationships. ICG can be part of citizen's organizations, religious communities, or simply a neighbour.
- **Evaluation Unit (EU):** The Evaluation Unit is composed by the Family Doctor, the Physician in Charge of the HC, the Head Nurse, and the Social Worker. The EU is a team of HC professionals which assesses the problem(s), defines an individual intervention plan (IIP), identifies the proper procedures, evaluates the results and verifies the achievement of the goals defined by the IIP. The EU is a temporary team.

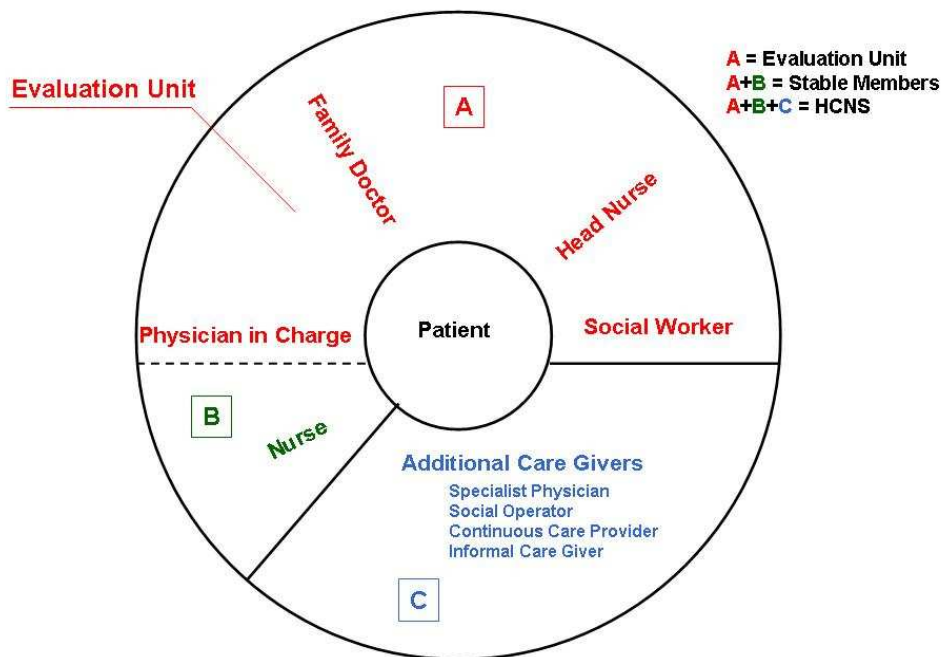


Figure 3 Actors of the HCNS

2.6.2 K4Care Implementation

The first design of the K4Care model was composed, basically, by a platform of agents and some knowledge sources (see Figure 4). In this model, two main layers are found: the first one, the K4Care platform, is divided in tree components the Servlet, the

Gateway agent and the Multi-Agent System (MAS). The second one is the Knowledge Layer, which stores all the medical knowledge about patients, diseases, and healthcare professionals.

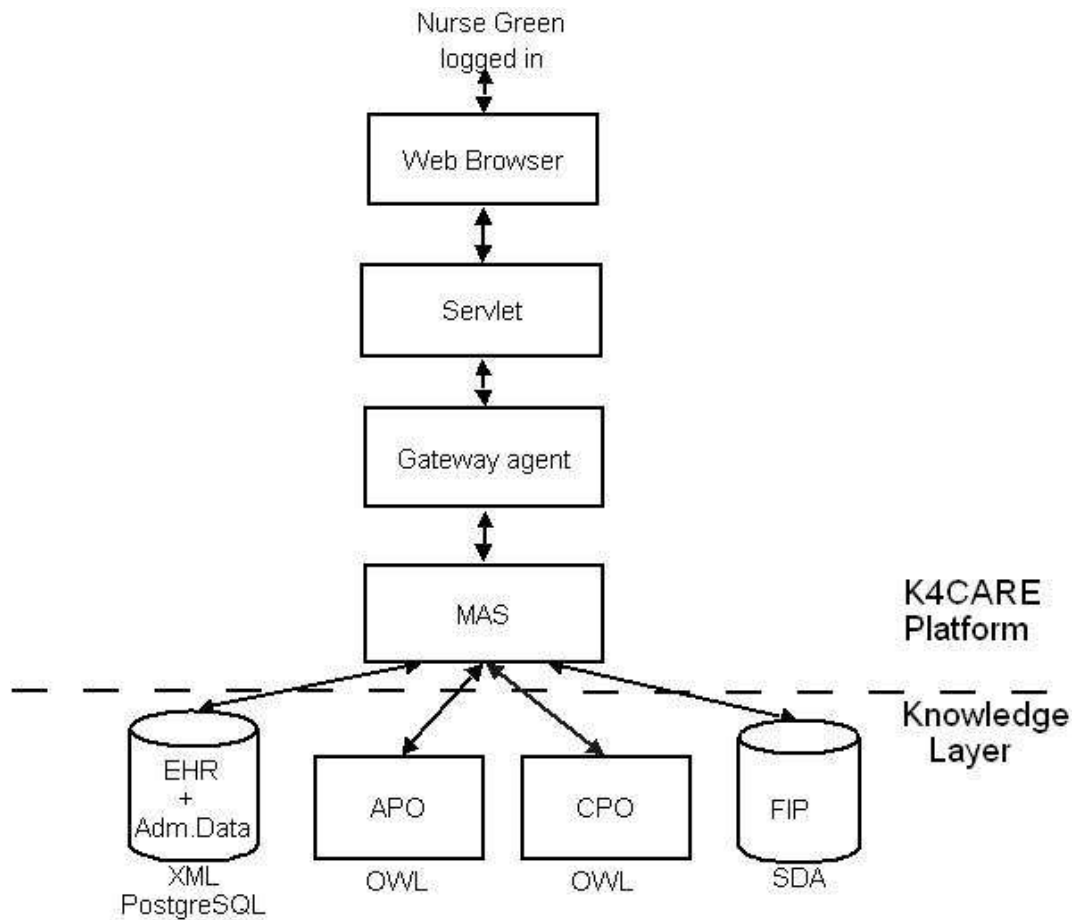


Figure 4. K4Care initial model

K4Care platform

The MAS manages the functionality of the system in the K4Care project. The MAS in K4Care is composed by different kinds of HealthCare agents, the agents which represent the staff (i.e. family doctors, nurses, etc.), and the agents which represent the patients of the system. In addition there is a group of another kind of agents (e.g. agents that execute Individual Intervention Plans and Formal Intervention Plans).

The K4Care model defines a set of services to assess patients. The main purpose of the MAS is to connect the Web Interface with the HealthCare Agents and to provide these services. The agents are in charge of executing the functionalities described in the D01 [4], this is the execution of long-term treatments, Individual Intervention Plans, and the execution of Procedures.

The connection between the User Interface (World Wide Web) and the agents in the system (HealthCare agents) is made through a set of gateway agents. The access to the K4Care MAS system is done through a web browser. The server side would be implemented using servlets. The entry point for the servlet to the MAS will be an agent

called Gateway Agent whose job will be to translate objects coming from the servlet to FIPA messages that go to the MAS.

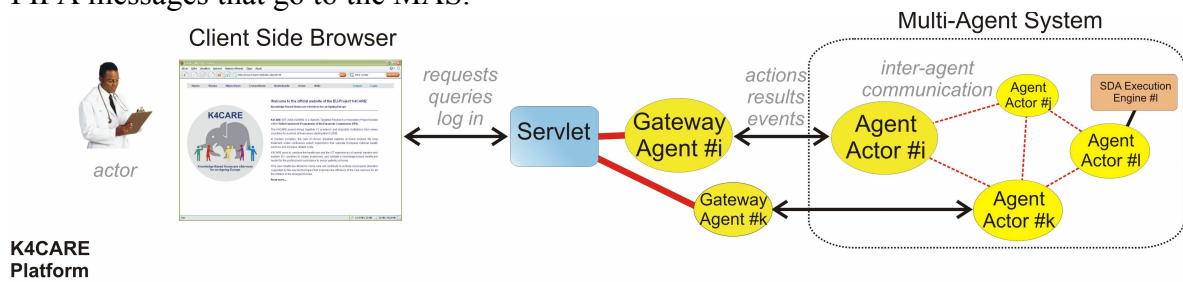


Figure 5 K4Care Platform

Knowledge Layer

The Knowledge Layer contains all the formal knowledge used in the K4Care. The knowledge in the Knowledge Layer is distributed in the following data sources:

- **Electronic Health Record (EHR)** and a relational data base: it stores administrative data about the actors implied in the K4Care and the information related to a patient, this means, his clinical history, etc.
- **Actor Profile Ontologies (APO)**: it formalises the knowledge related to all the agents involved in the care of chronic senior patients. The APO stores the permissions, procedures, services and documents related to each actor. This formal knowledge will be used to personalise the assistance to all the agents working with the platform: healthcare professionals, patients, and citizens in general; as they mutually interact.
- **Case Profile Ontologies (CPO)**: it formalises the knowledge of the ailments of these patients. The CPO contains the description of each disease that the patients can suffer.
- **Formal Intervention Plans (FIP)**: it formalises the treatment processes.
- **Procedures**: it is a set of actions combined in order to accomplish one service

3 DATA SOURCES

3.1 Electronic Health Records

3.1.1 General overview

An Electronic Health Record (EHR), also called Electronic Healthcare Record, is an important component in health informatics. It is defined as “digitally stored health care information about an individual’s lifetime with the purpose of supporting continuity of care, education and research, and enduring confidentiality at all times” [17]. An EHR includes all the information derived from the care of a patient, such as observations, laboratory tests, diagnostic imaging, reports, treatments, therapies, drugs administered, patient identifying information, legal permissions, and allergies.

A more formal definition is given in [18]: “The *basic-generic* definition for the EHR is a repository of information regarding the health status of a subject of care, in computer processable form”. Where, the term *subject of care* is used synonymously with *patient*. It is accepted that the most important characteristic of an EHR has to be the ability to share information between different authorized users. Thus, this requires interoperability of information inside the EHR and interoperability of EHR systems which exchange and share this information. Following this idea, the basic-generic EHR is divided in two specializations, sharable and non-sharable EHRs as illustrated in Figure 6. One of the sharable EHR considered is the “Integrated Care EHR” (ICEHR) as defined in [18]: “The Integrated Care EHR is defined as a repository of information regarding the health of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorized users. It has a commonly agreed logical information model which is independent of EHR systems. Its primary purpose is the support of continuing, efficient and quality integrated health care and it contains information which is retrospective, concurrent and prospective”.

The ICEHR is based on a standardised or commonly agreed logical information model which supports semantic interoperability. The *openEHR* Reference Model and the CEN 13606 Reference Model are examples of models which fit this definition.

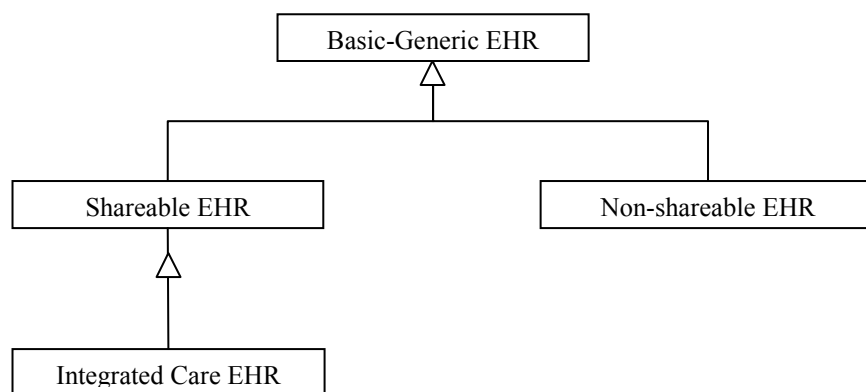


Figure 6 Specialisation of the Basic-Generic EHR

According to Cohen [7], the standards must consider the following aspects:

- healthcare messages exchange
- EHR object model
- healthcare terminology/ vocabulary

Additionally an EHR can provide a proper security mechanism. For example, authentication or encryption.

There are two main organizations that define standards:

- HL7 Health Level 7(www.HL7.org) USA
- CEN TC 251 (www.centc251.org) Europe

There are many standards under development; the ones that are leading the research are the CEN EN 13606 EHRcom and HL7 standards. Here, these standards and also the GEHR/openEHR standard, the Integrating the Healthcare Enterprise and the Digital Imaging and Communications in Medicine are introduced [1].

GEHR/openEHR

The GEHR/openEHR standard project began in January 1992, as a European Union initiative called Good European Health Report. The GEHR Project finished at the end of 1994. Later Australia entered into the project and the initiative was called Good Electronic Health Record. In 1999, it was established an open source foundation, the *openEHR* Foundation [22], and the name *openEHR* was adopted.

The *openEHR*'s information model is the **archetype**. An archetype is a re-usable, formal model of a domain concept. As defined in [2] an *archetype* is "a computable expression of a domain content model in the form of structured constraint statements, based on some reference model"

CEN EN 13606 EHRcom

CEN ENV/EN 13606 EHRcom is developed by CEN/TC 251, which is the technical committee on Health Informatics of the European Committee for Standardization. Its scope is standardization in the field of Health Information and Communications Technology to achieve compatibility and interoperability between independent systems and to enable modularity [10].

This standard is based in EHR exchange messages and adopts the archetype methodology of *openEHR*. The **Reference Model** defines the hierarchy of generic building blocs of the EHR through a set of classes.

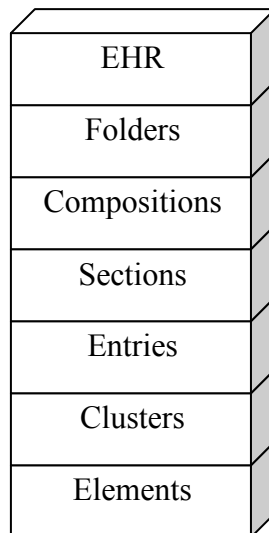


Figure 7 Components of the EHRcom Extract Reference Model

An important part of the standard is the information model adopted to structure the EHR information. In this standard, the data is organised into a hierarchy with seven levels (see Figure 7) [6].

HL7

HL7 (Health Level Seven) [13] is an ANSI accredited Standards Developing Organization (SDO) founded in 1987. HL7 is a not-for-profit volunteer organization that creates standards for the exchange, management, and integration of electronic healthcare information and the management, delivery, and evaluation of healthcare services.

The main concepts of HL7 are: On the one hand, the **Reference Information Model** (RIM) is an essential part of the HL7 Version 3 development process. The RIM is the reference for class and attribute definitions, represents the clinical data and the connections that exist between the information carried in the fields of HL7 messages. On the other hand, the **HL7 Clinical Document Architecture** (CDA) (see Figure 8) is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange [16] [15]. CDA documents are encoded in Extensible Markup Language (XML). CDA documents can be transmitted in HL7 messages designed to transfer clinical documents.

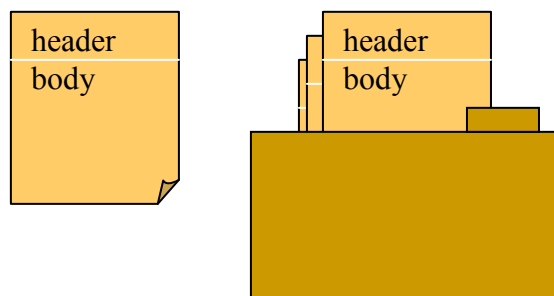


Figure 8. The CDA structure

IHE

Integrating the healthcare enterprise (IHE) is another organization that was created in 1998 by the Radiological the Radiological Society of North America (RSNA) [27] and the Healthcare Information and Management Systems Society (HIMSS) [14]. IHE don't develop standards, otherwise it is designed to stimulate the integration and support the use existing standards. In fact, it recommends and selects appropriate standards to be used in specific use cases and develops restrictions.

DICOM

The American College of radiology (ACR) and the National Electrical Manufacturers Association (NEMA) recognized the necessity of a standard for transferring images and associated information. DICOM: Digital Imaging and Communications in Medicine [9]. It is an standard for the communication of images, which addresses the exchange of digital information between medical imaging equipment and other systems. DICOM is typically used inside radiology, surgery, radiotherapy, and similar departments. The emphasis in these departments is high quality viewing and image processing.

3.1.2 Data management

The data management of great amounts of historical information is not an easy task. Sometimes, the management of this information can not be done with a simple data base. For example, some organizations manage its historical data or its corporate memory in a data warehouse. The data warehouse contains the raw material for management's decision support system. While operational systems are optimized for simplicity and speed of modification (online transaction processing, or OLTP) through heavy use of database normalization and an entity-relationship model, the data warehouse is optimized for reporting and analysis (on line analytical processing, or OLAP).

In medicine the problem of having a great amount of health care information about the patients with the purpose of supporting continuity of care, education, research, etc. has been solved using electronic health records. In the K4Care project, there is incorporated an electronic health record. The EHR contains the historical health data about the patients in form of XML documents. In addition, an interface between the electronic health record and the rest of the project is provided.

3.1.3 Database and Electronic Health Record in the K4Care project

The definition and implementation of the EHR in the K4Care project corresponds to Workpackage 2 (WP2). Initially, a study became of the different EHR standards (CEN EN 13606, HL7, DICOM, etc.). My contribution to WP2 in URV was to do this study [1]. CVUT designed and implemented the database. This design was discussed in a meeting in Tarragona.

The Electronic Health Record (EHR) contains digital stored health care information about a patient [17], as well as, documents and document schemas that health professionals manage during the patient assistance (Figure 9). In the K4Care project, the Electronic Health Record is stored in a relational database that stores XML [33] documents. In addition, this database stores all the administrative information related with the K4Care actors.

The database chosen was **PostgreSQL**. Some advantages of using this data base are:

- o rich SQL language (strong emphasize of the standard)
- o reliable (support for transactions)
- o BSD license
- o several languages for stored procedures including Java
- o CVUT has big experience with it (hundreds of databases for students)
- o great for people knowing SQL and experts in databases
- o convenient GUI: pgadmin3

The format messages in the system discussed were the HL7 and ENV 13606 standards. These messages only will be used to interchange data between the system and external institutions. In the K4Care system there will be a set of translation agents (K4Care Web Services) that will translate the internal representation of documents to messages. They will permit the interchange of data between the system and external institutions following the HL7 and ENV 13606 standards.

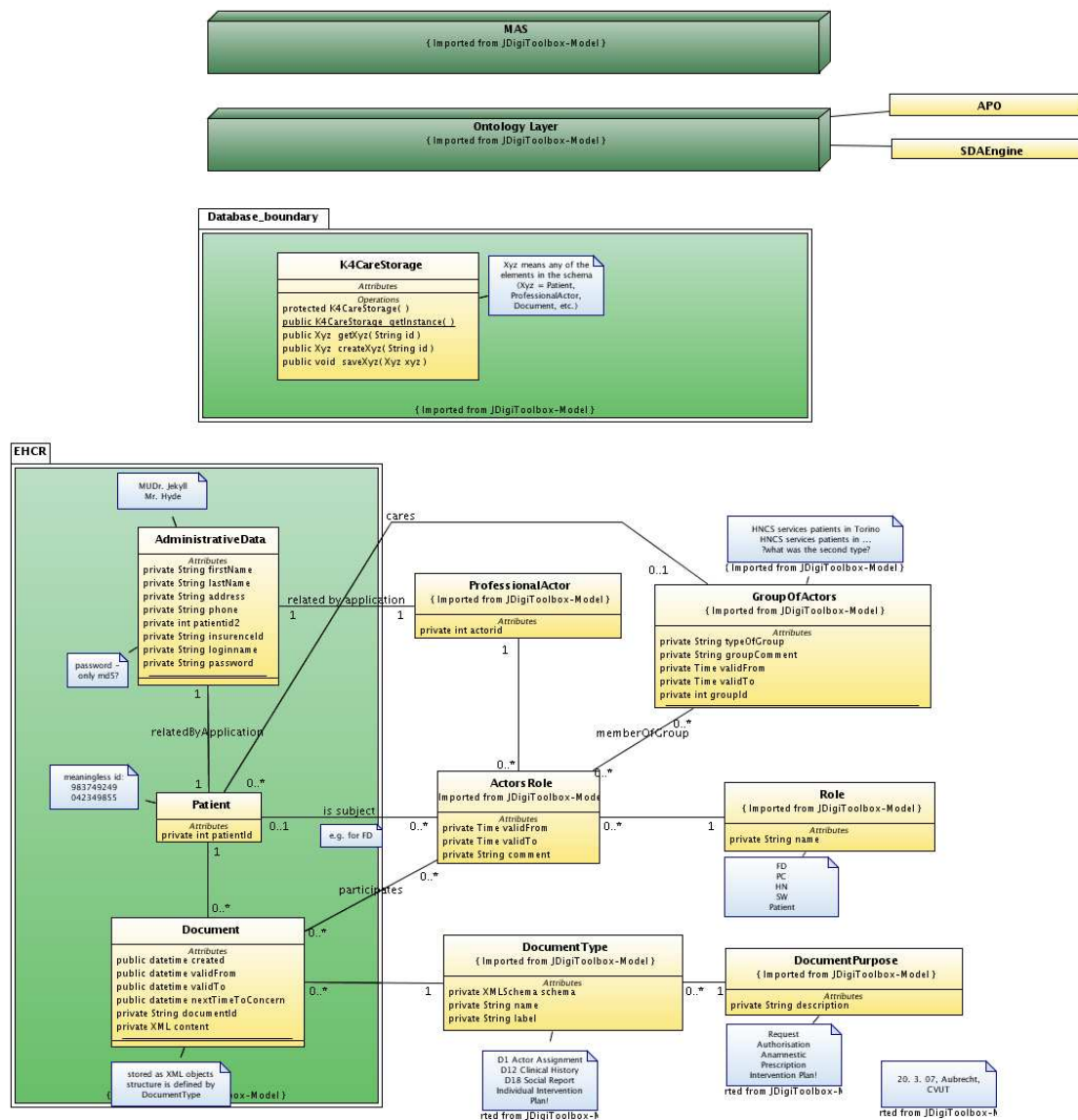


Figure 9 K4Care Data Base

Documents are a set of information units whose main purpose is to provide information about the care processes done by the actors to accomplish a service. The document storage is document oriented. Documents are seen as an atomic structure and stored as XML documents without knowledge of its internal structure from the database point of view in a table called Documents. Together with documents is stored their schema.

The table **DocumentType** contains the XML schemas for such type of documents and then the storage validates the documents stored. The table **DocumentPurpose** contains the purpose of each document schema (for example, a document that request information about the patient).

Documents are related to actors, but it is necessary to distinguish in which roles the actors act. In one document can be one person mentioned as a doctor, while in another it can be patient. For simple collecting documents it was necessary to introduce a denormalisation table **ActorsRole**.

There are 43 documents schemas defined in D01 (Deliverable 01). Seven of these documents schemas were chosen and created as sample XML schemas to make clearer the structure of the EHR documents planned to be used in K4Care. The seven documents chosen are: D01, D02, D11, D12, D13, D19, and D20.

In Table 2 there is a list of all document schemas types (in bold the chosen ones):

Type	Abbr.	Name	Description
Request	D1	Actor Assignment	Is the information that links an individual action to an individual HCP for an action (or series of actions) to be performed.
Authorization	D2	Actor Confirmation	Is the information that declares that the actor knows the assignment and accepts it.
Authorization	D3	Waiting List	The waiting list is automatically generated on the basis of requests, daily schedules, priorities. Is confirmed by the HN. Can be modified by the HN.
Authorization	D4	Daily Schedule	Daily Schedules are automatically generated on the basis of waiting lists and priorities. Different daily schedules exist for different services and actors. They are confirmed by the HN. They can be modified by the HN.
Request	D5	Message to the Patient	Is a message delivered to the HCP to inform that an action for a service is going to be performed and to make an appointment. Can be delivered by phone, via SMS or others.
Authorization	D6	Patient Confirmation	Is a message delivered by the HCP to inform that he/she accepts the appointment for an action to be performed. Can be delivered by phone, via SMS or others.
Authorization	D7	Patient Consent	Is the information which consents that a certain action (or series of actions) is accepted by the HCP and can be performed.
Authorization	D8	CCP Consent	Is the information which consents that a certain action (or series of actions) is accepted by the (legally responsible) CCP and can be performed, in case of HCP non capable of giving consent.
Authorization	D9	FD Authorization	Is the authorization that the FD (ultimate responsible of the HCP's care) gives for certain actions to be performed.
Request	D10	Request of Comprehensive Assessment	Is the request that allows the HCP to undergo a comprehensive assessment. Is done by the PC or the HN, after patient's admittance to the service.
Anamnesic	D11	MDE Scales	Set of forms filled in by the EU during the first problem assessment and/or in occasion of the periodical or end-treatment re-evaluation.
Anamnesic	D12	Clinical history	All the available pertinent clinical information of the HCP (previous test results, discharge sheets, consultations, previous treatment). It is written by the FD and PC; is read by EU and the other professionals in charge of the patient (according to their competencies in the process of care of the individual patient), by the patient him/herself.
Anamnesic	D13	Physical Examination Report	The report contains signs and symptoms of diseases and/or conditions. It is written by FD, PC, SP; can be updated in any occasion of evaluation. It is read by FD, PC, HN; SP and Nu in charge of the Patient.
Request	D14	Request of Diagnostic Examination	Request of diagnostic examination necessary to define the actual clinical condition of the HCP; is written by FD, PC, SP in charge of the patient.
Request	D15	Request of Laboratory Analysis	Request of laboratory analysis necessary to define the actual clinical condition of the HCP; is written by FD, PC, SP in charge of the patient.
Request	D16	Request of Consultation	Is the information to refer the HCP to a SP, to better define different aspects of care. It is usually done by the SP, but can also be done by the PC or the SP.
Anamnesic	D17	Consultation Report	Contains clinical observations and proposals made by the SP. Is usually addressed both to the patient and the FD.
Anamnesic	D18	Social Report	Contains the observations regarding social issues done by the SW at evaluation times.
Anamnesic	D19	Medical follow-up form	It is written by the FD or the PC during the follow-up activities.

	D20	Nursing follow-up form	It is written by the Nu or the HN during the follow-up activities.
	D21	CCP Report	It is written by the CCP during the follow-up activities. Can be used to indicate intervening difficulties or changes.
	D22	SO Report	It is written by the SO during the follow-up activities. Can be used to indicate intervening difficulties or changes.
	D23	ICG Report	It is written by the ICG during the follow-up activities. Can be used to indicate intervening difficulties or changes.
	D24	HCP Report	It is written by the HCP during the follow-up activities. Can be used to indicate intervening difficulties or changes.
	D25	Request of Extra CA	It is written by the FD when he detects such changes during the follow-up activities to deserve an extra CA of the HCP.
	D26	Definition of outcomes	Is written by members of the EU in order to define goals of the IP.
	D27	Re-evaluation Plan	Defines times and modalities to evaluate the accomplishment of the IP in terms of goals and results.
Prescription	D28	Prescription of Pharmacological Treatment	Medical instructions to treat diseases or disorders.
Prescription	D29	Prescription of Non-Pharmacological Treatment	Medical instructions to treat diseases or disorders.
Prescription	D30	Prescription of nursing care	Medical instructions define nursing care to be used to treat diseases or disorders.
Authorization	D31	Authorization of nursing care	It is written by PC to authorize the performance of nursing care.
Prescription	D32	Prescription of Assistive Devices	Medical definition of assistive devices to be used to support impairments and handicaps.
Request	D33	Request of Blood Gas Analysis	Request of BGA laboratory test.
Request	D34	Request of Blood Transfusion	Request of BT.
Anamnesic	D35	Transfusion Report	Document declaring that a BT has been performed.
Request	D36	Request of Certification	Request of a medical document to be used for legal purposes.
Anamnesic	D37	Certification	Medical document to be used for legal purposes.
Request	D38	Request of INR	Request of actions needed to perform an INR test .
Anamnesic	D39	INR Report	Contains the results of the INR test.
Request	D40	Request of Nursing Care	Request of activating nursing care, following the prescription of nursing care.
Request	D41	Social Support Request	Request of actions of social support, written by the SW.
Anamnesic	D42	Social Coaching Report	Definition of a series of social support action, written by the SW.
Anamnesic	D43	Information Sheet	Information addressed to the care givers, mainly to the non-professional ones.

Table 2. Documents for the Patient Care Services

In Figure 9 we can find the table Administrative Data. This table contains the personal information necessary to identify the actors that appear in the documents, such as the name, the surname, a numeric identifier or the address. This data has been separated from the medical information of the actors in order to avoid the risk of privacy violation of the actors (mainly the patients). So, if a medical document that is send into the system is captured by a third party, it will not be possible to know who it belongs to.

The link between the medical data and the personal identifiers will be done using a unique numeric identifier, which will be calculated using some appropriate translation functions that ensure the security and minimise the risk of identification.

Finally, two other tables are needed to manage the actors' behaviour in the system. On one hand, each professional actor could play one or more roles (table ActorsRole). That is, it is stored each actor role that an actor plays for its patients. Each role has a unique identifier. On the other hand, professional actors could be grouped in an evaluation unit (EU) to assess a patient. Table GroupOfActors stores these evaluation units, and relates each EU with the patient assessed.

On the access to the database: Database Boundary

The EHR developers proposed to create a Java API for the EHR. This API must provide the information contained in the EHR through Java objects. At the implementation level, the data store provides a **K4CareStorage** object (see Figure 10), which represents a single point access to the storage. By terms of patterns, it is a singleton with getXYZ(String id) methods returning objects according to their id. The XYZ are interfaces representing all objects appearing in the schema. The only class visible from Data Access is **K4CareStorage** singleton. In the following figure there is the proposed API:

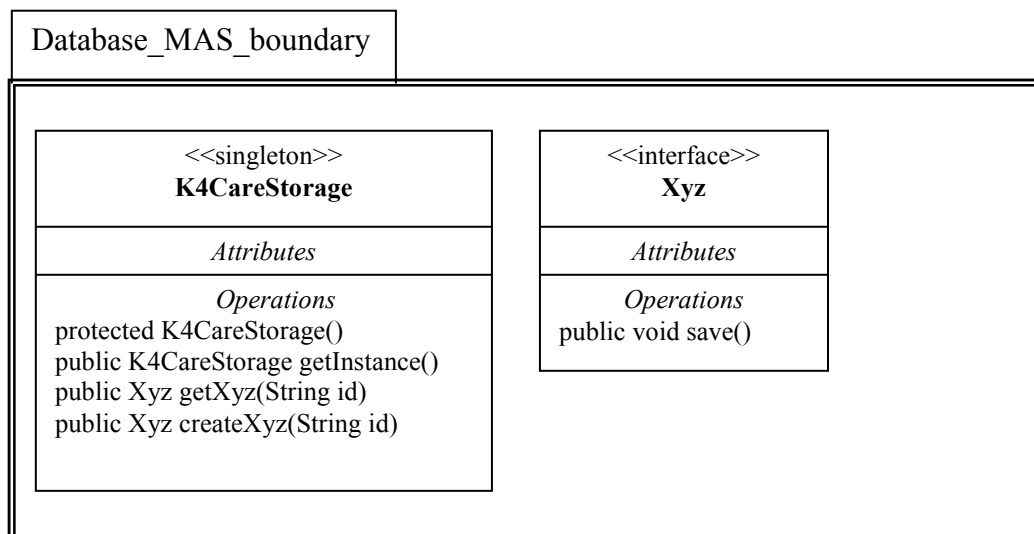


Figure 10 Data base boundary

3.2 Ontologies

3.2.1 General overview

Ontologies help to build better and more interoperable information systems [25]. There are many definitions about what an ontology is. One of the most known was given by Studer et al. [31]: “An ontology is a formal, explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. Explicit means that the type of concepts used and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private of some individual, but accepted by a group”. Sowa [28] explains the subject of an ontology as: “The subject of an ontology is the study of the categories of things that exist or may exist in some domain. The product of such a study, called an ontology, is a catalogue of types of things that are assumed to exist in a domain of interest D from the perspective of a person who uses a language L for the purpose of talking about D”. Neches et al.[20] give a definition focused on the form of an ontology. An ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary.

We can classify ontologies in several forms. An interesting classification was proposed by Guarino[12], who classified types of ontologies according to their level of dependence on a particular task or point of view:

- *Top-level ontologies*: describe general concepts like space, time, event, which are independent of a particular problem or domain. Examples of top-level ontologies are: Sowa’s [29] and Cyc’s [19].
- *Domain-ontologies*: describe the vocabulary related to a generic domain by specializing the concepts introduced in the top-level ontology. There are a lot of examples of this type of ontologies in e-commerce UNSPSC, NAICS, I medicine GALEN; UMLS; ON9, etc.;
- *Task ontologies*: describe the vocabulary related to a generic task or activity by specializing the top-level ontologies.
- *Application ontologies*: In application ontologies, concepts often correspond to roles played by domain entities.

We can find other classifications in [11]. On a hand, we can distinguish between: *Lightweight* ontologies, which usually are taxonomies, and *Heavyweight* ontologies, which model the domain in a deeper way and provide more restrictions on domain semantics. On the other hand, ontologies can be *highly informal* if they are expressed in natural language; *semi-informal* if they are expressed in a restricted and structured form of natural language; *semi-formal* if expressed in a formally defined language (i.e. Ontolingua, OWL); and *rigorously formal* if they provide well defined terms with formal semantics, theorems and proofs of properties.

There are many different techniques for modelling heavyweight ontologies:

- Using frames and first order logic: Modelling ontologies using frames and first order logic there are five different types of components: classes, relations,

functions, formal axioms and instances. *Classes* represent concepts. These classes usually are organized in taxonomies. *Relations* represent a type association between concepts of the domain. *Functions* are a special case of relations in which the n-th element of the relation is unique for n-1 preceding elements. *Formal axioms* model sentences that are always true. Finally, *instances* represent individuals or elements.

- Using description logic: Description Logics (DL) has three kinds of components: concepts, roles, and individuals. *Concepts* represent classes of objects. *Roles* represent binary relations between concepts. Finally, *instances* represent instances of classes.
- Using software engineering techniques: UML (Unified Modeling Language) sometimes is used as a technique for modeling ontologies. *Classes* are represented with boxes. *Relations* are expressed as associations between classes. *Formal axioms* must be represented in OCL, though there is no standard support for this language in common CASE tools.
- Using database technology: We can model an ontology using an Entity-Relationship (ER) diagram. We can model *classes* using the ER-entities, *attributes* using ER-attributes, *relations* between classes with ER-relations between ER-entities or *instances* using the sentence insert.

In the K4Care project, a group of physicians has developed two ontologies in order to reach an efficient way to store and communicate general medical knowledge and patient-related information: An Actor Profile Ontology and a Case Profile Ontology.

3.2.2 OWL Language

The OWL Language has been created by the W3C Web Ontology Working Group [23]. OWL is designed for use by applications that need to process the content of information instead of just presenting information to humans. OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema (RDF-S) by providing additional vocabulary along with a formal semantics. OWL has three increasingly-expressive sublanguages: OWL Lite, OWL DL, and OWL Full. The ontologies of the K4Care project are written in OWL. OWL is derived from DAML+OIL language and it builds upon RDF(S).

3.2.3 Ontologies in the K4Care project

There are two OWL ontologies in the K4Care: The Actor Profile Ontology, and the Case Profile Ontology.

3.2.3.1 Actor Profile Ontology

The Actor Profile Ontology (APO) stores the data of the actors involved into the sanitary model K4Care (Figure 12). As we said, in the HCNS, these individuals are the members of three different groups of HC actors. In K4Care model this people are organized in three groups of actors: patients, stable members, and additional care givers. They are organised in a hierarchical structure.

Moreover, the APO also stores data about the services, procedures and actions. K4Care provides services to the patients. The APO contains the services in which actors can take part, the procedures of those services (a non-ordered list of actions that conform a service) and the particular actions that they can perform. In addition the ontology stores documents, and permissions of the different kinds of actors to read and/or write a document. The APO is represented by an ontology written in OWL [23]. The APO Ontology was designed by URV and FSL teams [5].

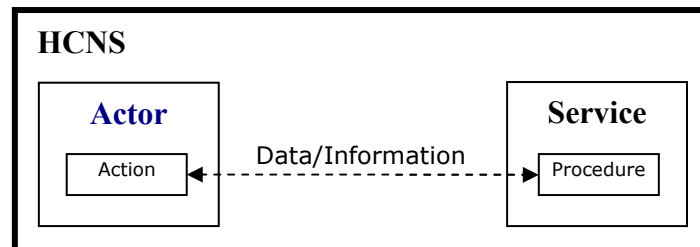


Figure 11 K4Care HCNS

The APO is composed by a hierarchy of OWL classes and relations or properties between them. The description of the main classes of the APO is:

- Entity: An Entity is something that can perform an action in the K4Care project. This class is divided in two subclasses:
 - Actor: The Actor class represents somebody in the K4Care. Actors are people interacting with the HC system. The class Actor is divided in subclasses such as Stable Members (composed by Family Doctors, Physicians in Charge, Head Nurses, Social Workers and Nurses), Additional Care Givers (Specialist Physician, Social Operator, Continuous Care Provider, Informal Care Giver), and Patients.
 - Evaluation Unit: The Evaluation Unit class represents an evaluation unit (a group with a Family Doctor, a Physician in Charge, a Head Nurse, and a Social Worker).
- Services: The service class represent a K4Care Services. K4Care provides a set of services for the care of HCP. These services are classified into Access services, Patient Care services, and Information services.
- Procedure: this class represents a procedure associated to a service.

- Action: The class Action represents a set of simple actions that are executed inside one or more procedures.
- Document: This class represents the documents that are read or written during the execution of one action. These documents are stored in the EHR.

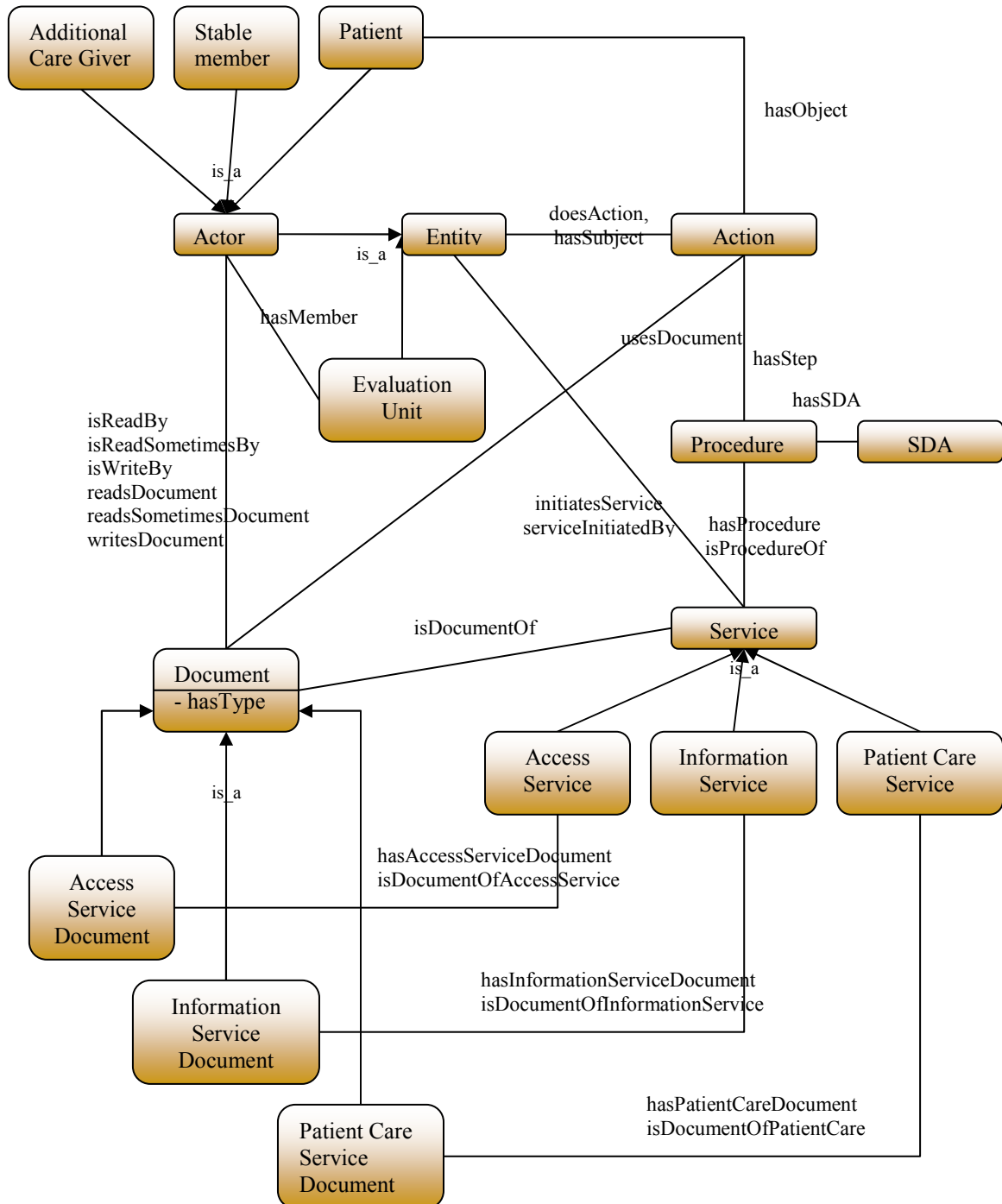


Figure 12 APO structure

3.2.3.2 Case Profile Ontology

Case Profile Ontology (CPO) contains knowledge about some syndromes that will be considered in the K4Care prototype immobility and cognitive impairment. All the information regarding these syndromes is organised in the CPO: symptoms, interventions, diseases, etc. The CPO is represented by an ontology encoded in OWL [23]. The CPO Ontology was designed by URV, UNIPG and FSL teams.

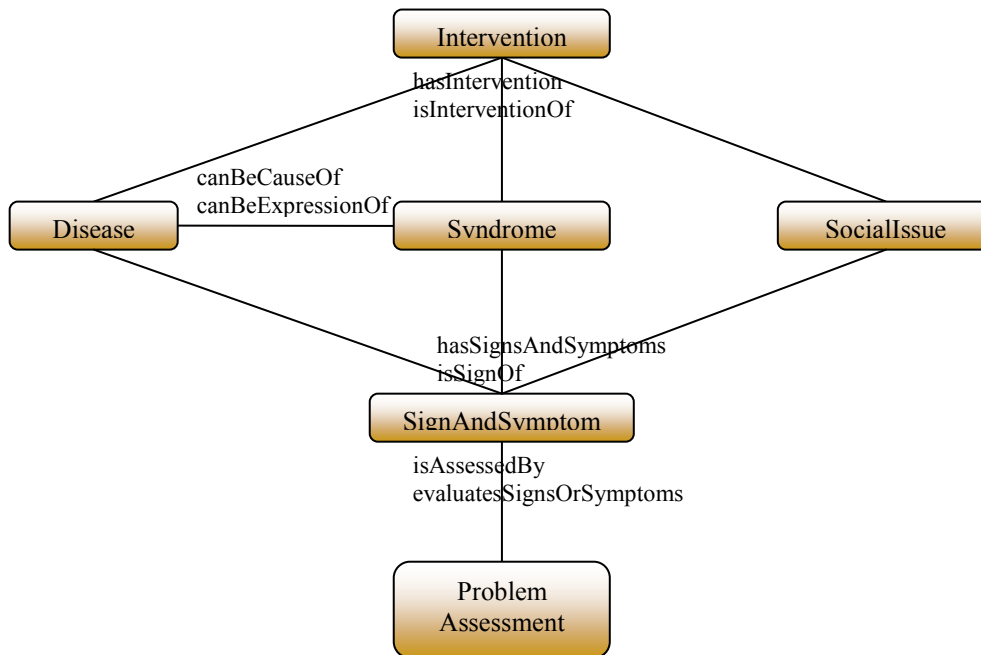


Figure 13 CPO Ontology

The CPO is composed by a hierarchy of OWL classes and relations or properties between them. The description of the main classes of the CPO is:

- **ProblemAssessment:** This class is devoted to store the set of actions needed to detect the whole series of HCPs diseases, conditions, and difficulties, from both the medical and social perspectives.
- **Disease:** This class represents the diseases that a HCPs could suffer.
- **SignAndSymptoms:** The class SignAndSymptoms defines a set of signs and symptoms. One or a group of symptoms can be the expressions of a disease, or a disease can be the cause of one or more symptoms.
- **Social Issue:** This class represents social problems of the patient (for example, the patient not has enough money to pay his drugs or has nobody to take care of him).
- **Intervention:** The intervention class is composed by actions to cure, take care, and solve social problems of the patient.

3.3 Modelling the patients' treatment

Patients' treatments can be modelled using clinical guidelines. In this section we will explain what a guideline is and we will explain how patients' treatments will be represented in the K4Care model.

3.3.1 Clinical Guidelines

The US National Cancer Institute defines Clinical Guidelines as documents developed to help health care professionals and patients make decisions about screening, prevention, or treatment of a specific health condition. Clinical Guidelines contain a set of directions or principles to assist the health care practitioner with patient care decisions about appropriate diagnostic, therapeutic, or other clinical procedures for specific clinical circumstances. Medical guidelines are intended to ensure consistent high quality clinical practice and provide some benefits to both patients and health managers [8].

There are guidelines published by international healthcare organizations as the *National Library of Medicine* and the *National Guideline Clearinghouse* in the USA, the *New Zealand Guidelines Group*, the *Scottish SIGN*, etc.

The representation of Clinical Guidelines are composed by several elements to be modelled, such as actions, required patient data, decisions to be taken, constraints between tasks, temporal constraints in a global planning, etc. We can find some formal languages to model computer-interpretable clinical guidelines, such as *PROforma*, *EON*, *GLIF* or *Asbru* [24, 3].

3.3.2 Formal Intervention Plans

Formal Intervention Plans (FIPs) represent procedural knowledge about treatments of syndromes and diseases. These FIPs store the guidelines to assist patients who suffer from particular ailments or diseases. Some of them have been obtained from the recommendations of the World Health Organization; others are being defined by the doctors' team that participate in the project. FIPs contain indications to all the actors involved in the care process (i.e. healthcare professionals, patients and relatives) in order to provide the best coordinated action plan. FIPs are represented in a graphical language called *SDA** (States, Decisions, and Actions) [26].

Each patient has different particularities. FIPs are general guidelines that have to be adapted to these particularities before they are applicable to a particular patient. In the K4Care project the structure resulting from this adaptation is called **individual intervention plan (IIP)** and will be stored in the patient's EHR.

3.3.3 SDA* Model

SDA stands for State-Decision-Action, SDA* designed by David Riaño [26] is stored in XML and represents the repetition of states, decisions and actions in order to describe health care procedural knowledge. *States* are used to describe patient conditions or situations. It provides a response to the fact that a disease, ailment, pathology, or syndrome can present alternative degrees of evolution whose treatment must be distinguished. Decisions represent alternative options whose selection depends on the available information about the patient. *Decisions* intended to orientate a general purpose treatment to the particular characteristics of the patient. Finally, *Actions* are proper treatment steps. States, decisions, and actions are combined to form a joined representation of how to deal with a particular health care situation.

In Figure 14 there are an example of FIP represented using the SDA* model. Cycles represent states, rhombuses represent decisions, and squares represent actions. An arrow that goes from one element (in-element) to another (out-element) represents a *connector*.

SDA* model has two types of optional temporal constraint: constraints related to the terms in a SDA* element and constraints related to the connectors. The time constraints of the terms are composed by [start, end, frequency] (the term is observed from the start time, to the end time with the frequency indicated). The second kind of time constraints is related to the SDA* connectors and it has the form [min, max]. They represent delays; the evolution from the in-element to the out-element of the connector takes between min and max times.

Parallelism is admitted by the SDA* model from the point of view of the patient following a SDA* procedure (patient-oriented). The patient follows a single treatment in which several events may concur in time. In this approach parallelism means that actions of the treatment overlap in time, but not means that the patient is following several treatments at the same time (procedure-oriented).

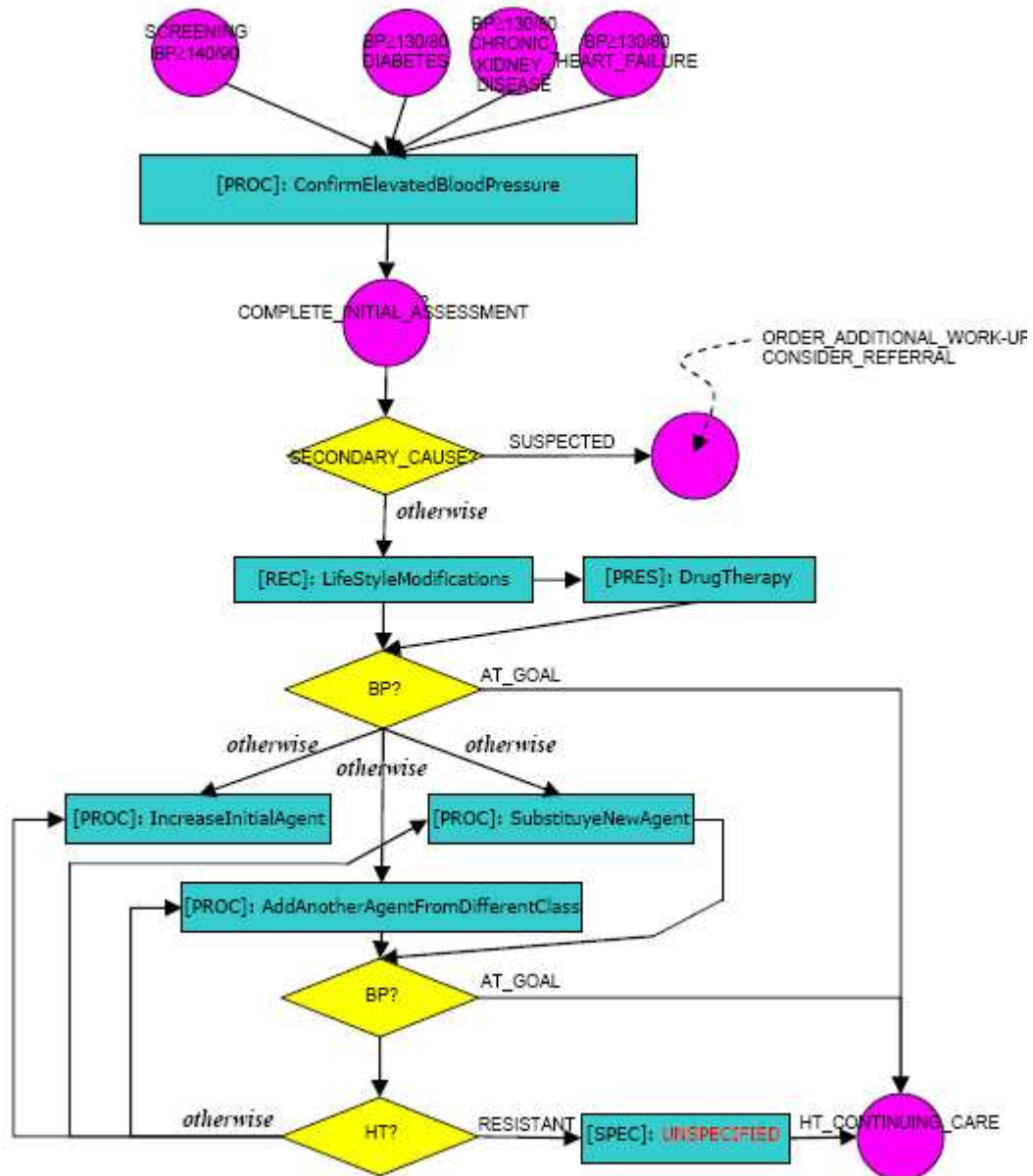


Figure 14 SDA that represents the process of diagnosis and treatment of hypertension.

PART II: PROJECT DEVELOPMENT

4 PROCEDURE REPRESENTATION IN K4CARE

As said before, the main problems detected with the original specification of procedures were that the actions are specified as a list of task in a generic way in Deliverable01 (D01) [4], the lack of a control flow definition and link between actions and documents.

4.1 Initial procedure representation

In the document D01, the services to be offered in K4Care are formalized as procedures, which are sequences of actions to be performed. The doctors' team identified the steps to be followed and provided a specification of the procedures in this project deliverable. However, there is not enough information for the procedure representation. It is found that the available information contains a lot of implicit and incomplete information necessary for the design of the procedures.

We identified some elements that also need to be formalized in order to be able to build a K4Care procedure. In particular:

- Doctors specified procedures in a generic way, procedures are specified as a list of steps that has to be preformed but they did not specify which concrete actions are used (D01 contains the description of all the actions available in the K4Care and the actors that perform such actions.

BO.1	provide information
BO.2	ask information
BO.3	refer the admitted patient for CA
BO.4	assign actor
BO.5	assign members of EU
BO.6	confirm or modify waiting lists
BO.7	schedule activity
BO.8	send message to the patient
BO.9	supervise HCP information
BO.10	authorize nursing care service
BO.11	forward the Blood Transfusion request
BO.12	send Transfusion Report
BO.13	actor confirmation

Table 3 Back Office list of actions

- The flow between the procedure steps has to be explicitly defined, since not always a procedure is a simple sequence of actions, but may contain loops and decisions. We must know also if there are different results for a particular procedure, and if it is possible to have cycles, that is, to return to a previous step depending on the result of some procedure.

- Doctors provided a list of documents for the service but they did not specify in which actions are used.

4.2 Revision of the procedure representation model

All these information could be given using flow diagrams associated to each procedure, including all possibilities at every step. One node of the flow diagram must correspond to one action required to perform the procedure. The arrows between nodes must express the sequence to be followed between actions. Alternative possibilities have to be considered at every step. All the possible results of a procedure must be indicated¹.

Then, agents could navigate through or execute the K4Care procedures following a flow diagram, that is, in the flow diagram there should be enough information to allow the Multi-Agent System (MAS) to control the sequence of actions to be performed.

We identified three essential elements required to perform and manage a K4Care procedure associated to the nodes of the flow diagram:

- The actors implied in an action. That is, who performs each action. An action in a procedure can be performed by different actors.
- The concrete actions implied in a procedure. A procedure is a set of actions. We must know which actions compose each procedure and which is the control flow of these actions in the procedure.
- The documents required to perform the actions. In K4Care in many cases an action is the result of create, read or write a document (documents are stored in the K4Care data-base).
- The actor's permission to read/ write the documents. It is required to specify, for every actor, if he can
 - a. Create (C) a document.
 - b. Modify (M) a document.
 - c. Consult (Query) (Q) a document.

In D01 are defined the permissions of the actors for reading and writing documents. That is, when an actor can write he can create and modify a document and when he can read he can query for a document.

To solve the lack of information in procedures, first of all, doctors were required to indicate at which step the documents are used. As said, there is also a lack of information about the control flow between the actions in the service. It is required to make explicit the sequence of actions, which are the decision points and to identify if some actions could be done in parallel or are cycles. For these reason, we had to work together with doctors to obtain all this information. The result of this work is represented in Table 4. K4Care services were divided into access services, patient care services, and information services. The first group is about how actors and working

¹ These Flow Diagrams cannot be represented using ontologies, because ontologies represent the know-what, and the Flow Diagrams represent the know-how, that is, how to use the information in the ontologies. Another representation mechanism must be chosen, we will think about it if the idea of having Flow Diagrams is correct.

teams are created, updated, and destroyed in the K4Care model. The second group is about how the actors of the model interact to provide an effective and efficient home care. The third group gathers all the services devoted to provide information, outside the actual performance of single services.

Description	Action	Document
3. Problem Assessment and Re-Evaluation		
S3.1. Comprehensive Assessment (CA)		
a) The PC or the HN refers the admitted patient for a CA.	BO.3 refer the admitted patient for CA	D10 Request of Comprehensive Assessment
(b) The HN assigns the members of the EU.	BO.5 assign members of EU	D1 Actor Assignment
	BO.13 actor confirmation	D2 Actor Confirmation
(c) The HN sends a message to the patient to make an appointment.	BO.8 send message to the patient	D5 Message to the Patient
(d) The HCP confirms the appointment	P.1 confirm appointment	D6 Patient Confirmation
(e) The EU makes the patient's assessment at home according to a standardized interview (<i>Multi-Dimensional Evaluation</i>).	EU.1 evaluate through scales	D11 MDE Scales
(f) FD or PC performs <i>Clinical Assessment</i> and <i>Physical Assessment</i> .	S3.3 Clinical Assessment	
(g) The SW performs the <i>Social Needs and Social Network Assessment</i> .	S3.8 Social Needs and Network Assessment	
(h) The HCP provides the necessary information. In case of a non-compliant or non reliable HCP, the CCP provides the necessary information.	BO.1 provide information	
(j) The HN performs Case Management or Back Office proper actions	S5.1.A Case management A	
S3.2. Multi-Dimensional Evaluation		
(a) A standardized interview according to a set of standardized evaluation scales is performed by the EU in occasion of the Comprehensive Assessment (after patient's admission). The same interview is repeated in occasion of the periodical and end-treatment re-evaluation(s), as defined inside the IP or on request of the FD during the <i>follow-up</i> .		
(b) The PC or the HN refers the admitted patient for a CA	BO.3 refer the admitted patient for CA	D10 Request of Comprehensive Assessment
(c) The re-evaluation is defined inside the IP.	EU.5 schedule re-evaluations	D27 Re-evaluation Plan
(d) The re-evaluation is requested by the FD, based on	M.FD.2 request of re-evaluation	D25 Request of Extra re-evaluation

elements deriving from the follow-up.			
(e) The EU interviews the HCP according to a set of standardized evaluation scales.	EU.1	evaluate through scales	D11 MDE Scales
(f) The HCP provides the necessary information. In case of a non-compliant or non reliable HCP, the CCP provides the necessary information.	BO.1	provide information	
S3.5. Request of Diagnostic Examination			
(a) The FD, PC, SP write a request of Diagnostic Examination.	M.3	request Diagnostic Examination	D14 Request of Diagnostic Examination
(b) The HN performs Case Management's proper actions.	S5.1.B	Case management B	
S3.6. Request of Laboratory Analysis			
(a) The FD, PC, SP write a request of Laboratory Analysis.	M.4	request Laboratory Analysis	D15 Request of Laboratory Analysis
(b) The HN performs Case Management's proper actions.	S5.1.B	Case management B	
S3.7. Consultation			
(a) The FD refers the HCP to the SP.	M.9	refer to SP	D16 Request of Consultation
(b) The HN performs Case Management's proper actions.	S5.1.C	case management C	
(c) The HN sends a message to the patient to make an appointment.	BO.8	send message to the patient	D5 Message to the Patient
(d) The patient confirms the appointment.	P.1	confirm appointment	D6 Patient Confirmation
(e) The SP makes a patient's assessment (Clinical Assessment, Physical Assessment).	S3.3	Clinical Assessment	
	S3.4	Physical Examination	
(f) The SP writes a consultation.	M.SP.1	write consultation report	D17 Consultation Report
(g) The SP eventually requests laboratory tests, and/or other diagnostic procedures.	S3.6	Request of laboratory analysis	
	S3.5	Request of diagnostic examination	
(h) The SP eventually refers patients for different consultations.	M.9	refer to SP	D16 Request of Consultation
(i) The SP prescribes medication and treatment, under an agreement with the FD.	S4.2	Prescription of Pharmacological Treatment	
	S4.3	Prescription of non-pharmacological treatment	
(j) The FD authorizes pharmacological/non-pharmacological treatment	M.FD.3	authorize treatment proposed by SP or PC	D9 FD Authorization

proposed by the SP.		
S3.8. Social Needs and Social Network Assessment		
(a) The SW makes an assessment of the patient's social needs and social network in order to define the IP		
(b) According to an interdisciplinary scale the SW identifies, analyses and evaluates the patient's social needs in order to define the IP. The SW makes a contextual examination in skills and resources of the patient's family and the care providers' group.	S.1 assess social needs and network	D11 MDE Scales
(d) The SW evaluates the results of the patient's program for social assistance and defines best practice.	S.3 supervise achievement of social outcomes	D18 Social Report
S3.9. Follow-up		
(a) The evolution of clinical and functional status of HCP is assessed according to scheduled controls and/or in case of emerging medical and social issues by the FD, SW, Nu.	EU.4 schedule controls	D26 IP
(b) The HN sends messages to the patient to make appointments.	BO.8 send message to the patient	D5 Message to the Patient
(c) The patient confirms the appointments.	P.1 confirm appointment	D6 Patient Confirmation
(d) The FD monitors parameters indicating health status and overall condition of the patient through evaluation scales, Clinical Assessment, Physical Examination, Request of Diagnostic Examination, Request of Laboratory Analysis, Consultation.	EU.1 evaluate through scales	D11 MDE Scales
	S3.3 Clinical Assessment	D12 Clinical history
	S3.4 Physical Examination	D13 Physical Examination Report
	S3.6 Request of laboratory analysis	
	S3.5 Request of diagnostic examination	
	M.9 refer to SP	D16 Request of Consultation
(e) The FD fills in the medical follow-up form.	M.10 write medical follow-up	D19 Medical follow-up form
(f) The FD refers the HCP to a SP when he/she needs specific contribution from different professionals to maintain the necessary care of the patient and in order to avoid unnecessary admissions to	M.9 refer to SP	D16 Request of Consultation

hospital.			
(g) The Nu fills in the Nursing follow-up form during the scheduled activities.	N.26	write Nursing follow-up	D20 Nursing follow-up form
(h) The SW evaluates periodically the patient's program for social assistance and may improve it.	S.3.8	Social Needs and Network Assessment	
(i) The SW periodically supervises and improves the care providers' group.	S.3	supervise achievement of social outcomes	D18 Social Report
	S.6	write social report	D18 Social Report
(j) Trained actors can use part of the Multi-Dimensional Evaluation (one or more scales) to define special issues.	EU.1	evaluate through scales	D11 MDE Scales
(k) Other care-givers (all the actors not specified here) could provide information about HCP status.	BO.1	provide information	D21 CCP Report
			D22 SO Report
			D23 ICG Report
			D24 HCP Report
(l) When intervening conditions substantially modify HCP's overall status, re-evaluations can be requested by the FD, apart from the re-evaluation defined inside the IP.	M.FD.2	request of re-evaluation	D25 Request of Extra re-evaluation
(m) The HN performs Case Management's proper actions.	S5.1.B	Case management B	
4. Intervention Plan Definition.			
S4.1. Planning Intervention Plan			
(a) The EU defines an intervention plan – based on Comprehensive Assessment information – indicating means and timing of HCP's care and assigning the proper actors in order to accomplish defined outcomes.	EU.2	define intervention plan	D26 IP
(b) Defined goals are indicated.	EU.3	define outcomes	D26 IP
(c) The SW plans an individual program for social assistance in order to provide and start up all the social services the HCP needs (i.e. social sanitary assistance, financial assistance, legal aids, home shortages and obstacles, the supply of ambulation devices, etc). The SW defines a priority list of the patient's social needs to fulfil. The SW defines, together with the patient's family and the care providers' group, their skills and resources in order to organize and empower them inside the IP.	S.2	define social intervention	D26 IP
(f) The EU schedules	EU.5	schedule re-evaluations	D27 Re-evaluation Plan

periodical and end-treatment re-evaluations.			
(g) The EU schedules periodic controls of the FD, SW.	EU.4	schedule controls	D27 Re-evaluation Plan
(h) The HCP agrees on the proposed interventions. In case of a non-compliant or non reliable HCP, the CCP agrees on the proposed interventions.	P.3	give consent	
(j) The HN provides the Case Management.	S5.1.B	Case management B	
(k) The HN looks after the fulfilment of the IP.	CM.1	supervise IP	
	CM.2	control performance of activities	
	CM.3	supervise achievement of outcomes	
S4.2. Prescription of Pharmacological Treatment			
(a) The FD, PC, SP write a prescription for Pharmacological Treatment.	M.5	prescribe Pharmacological Treatment	D28 Prescription of Pharmacological Treatment
(b) The FD authorizes pharmacological treatment proposed by the SP or PC.	M.FD.3	authorize treatment proposed by SP or PC	D9 FD Authorization
S4.3. Prescription of Non-Pharmacological Treatment			
(a) The FD, PC, SP write a prescription for non-Pharmacological Treatment.	M.6	prescribe non-Pharmacological Treatment	D29 Prescription of Non-Pharmacological Treatment
(b) The FD authorizes non-pharmacological Treatment proposed by the SP or PC.	M.FD.3	authorize treatment proposed by SP or PC	D9 FD Authorization
(c) In case of involvement of third actors, proper case management activities are performed by the HN.	BO.4	assign actor	D1 Actor Assignment
	BO.13	actor confirmation	D2 Actor Confirmation
S4.4. Prescription of Nursing Care			
(a) The FD, SP, PC write a prescription of nursing care.	M.8	prescribe nursing care	D30 Prescription of nursing care
(b) The FD and PC jointly authorize nursing care proposed by the SP.	M.FD.6	authorize nursing care	D31 Authorization of nursing care
(c) The PC authorizes nursing care proposed by FD.	BO.10	authorize nursing care service	D31 Authorization of nursing care
S4.5. Prescription of Assistive Devices			
(a) The FD, PC, SP write a prescription for assistive devices.	M.7	prescribe assistive devices	D32 Prescription of Assistive Devices
5. Intervention Plan Performance.			
S5.1.A Case Management A			
(a) The HN confirms or modifies waiting lists.	BO.6	confirm or modify waiting lists	D3 Waiting List
(b) The HN confirms or modifies daily schedules.	BO.7	schedule activity	D4 Daily Schedule
S5.1.B Case Management B			
(a) The HN assigns the	BO.4	assign actor	D1 Actor Assignment

pertinent actor(s) to the HCP.	BO.13	actor confirmation	D2	Actor Confirmation
(b) The HN confirms or modifies waiting lists.	BO.6	confirm or modify waiting lists	D3	Waiting List
(c) The HN confirms or modifies daily schedules.	BO.7	schedule activity	D4	Daily Schedule
	BO.8	send message to the patient	D5	Message to the Patient
	P.1	confirm appointment	D6	Patient Confirmation
	P.3	give consent	D7	Patient Consent
			D8	CCP Consent
S5.1.C Case Management C				
(a) The HN assigns the pertinent actor(s) to the HCP.	BO.4	assign actor	D1	Actor Assignment
(b) The HN confirms or modifies waiting lists.	BO.13	actor confirmation	D2	Actor Confirmation
	BO.6	confirm or modify waiting lists	D3	Waiting List
(c) The HN confirms or modifies daily schedules.	BO.7	schedule activity	D4	Daily Schedule
S5.1.D Case Management D				
(a) The HN assigns the pertinent actor(s) to the HCP.	BO.4	assign actor	D1	Actor Assignment
	BO.13	actor confirmation	D2	Actor Confirmation
S5.1.E Case Management E				
(a) The HN assigns the pertinent actor(s) to the HCP.	BO.4	assign actor	D1	Actor Assignment
	BO.13	actor confirmation	D2	Actor Confirmation
(b) The HN confirms or modifies waiting lists.	BO.6	confirm or modify waiting lists	D3	Waiting List
S5.2. Special Medical Services				
Blood Gas Analysis				
(a) The FD, PC, SP refers his patient to the HC service for a BGA or the BGA is part of the intervention plan.	S3.6	Request of laboratory analysis	D33	Request of Blood Gas Analysis
(b) The HN performs Case Management's proper actions.	S5.1.C	Case management C		
(c) The HN sends a message to the patient to make an appointment.	BO.8	send message to the patient	D5	Message to the Patient
(d) The patients confirms the appointment.	P.1	confirm appointment	D6	Patient Confirmation
	P.3	give consent	D7	Patient Consent
			D8	CCP Consent
(e) The SP performs the arterial blood collection at patient's home.	M.SP.2	arterial blood collection		
(f) The SP (or other instructed actor) takes the specimen to the laboratory.	M.SP.3	takes specimen to laboratory		
Blood Transfusion				
(a) On the basis of a low blood cell count (red cells and haemoglobin concentration), the FD (or the PC, or the SP) refers the HCP for a BT.	M.13	refer for transfusion	D34	Request of Blood Transfusion
(b) The HCP gives consent. In case of a non-compliant or non reliable HCP, the CCP gives consent.	P.3	give consent	D7	Patient Consent
(c) The PC forwards the Blood	BO.11	forward the Blood	D34	Request of Blood

Transfusion request to the Blood Transfusion Service.		Transfusion request		Transfusion
(d) The HN schedules two blood specimens collections at 24-hour interval (only one for the following BTs) for cross-reaction tests.	BO.7	schedule activity	D4	Daily Schedule
(e) The HN performs Case Management's proper actions.	S5.1.D	Case management D		
(f) The HN sends messages to the patient to make appointments.	BO.8	send message to the patient	D5	Message to the Patient
(g) The patient confirms the appointments.	P.1	confirm appointment	D6	Patient Confirmation
(h) The Nu performs the activities.	N.1	Specimen Collection (blood, urine, faeces).		
(i) The HN alerts the Physician in charge of the transfusion.	BO.4	assign actor	D1	Actor Assignment
	BO.13	actor confirmation	D2	Actor Confirmation
(j) The Physician in charge (SP) of the transfusion collects the blood bags.	M.SP.4	collect blood bags		
(k) The Physician in charge (SP) of the transfusion sends a message to the patient to make an appointment	BO.8	send message to the patient	D5	Message to the Patient
(l) The patient confirms the appointment.	P.1	confirm appointment	D6	Patient Confirmation
(m) The Physician in charge (SP) of the transfusion performs the transfusion.	M.SP.5	perform the transfusion		
(n) The Physician in charge (SP) of the transfusion delivers to the HCNS a Transfusion Report	M.SP.6	write transfusion report	D35	Transfusion Report
(o) The PC or the FD refers the HCP for a post-transfusion blood count.	S3.3	Clinical Assessment	D15	Request of Laboratory Analysis
(p) The HN schedules the blood specimen collections at 24-hour interval.	BO.7	schedule activity	D4	Daily Schedule
(q) The HN performs Case Management's proper actions.	S5.1.D	Case management D		
(r) The HN sends a message to the patient to make an appointment.	BO.8	send message to the patient	D5	Message to the Patient
(s) The patient confirms the appointment.	P.1	confirm appointment	D6	Patient Confirmation
(t) The Nu performs the activity.	N.1	Specimen Collection (blood, urine, faeces).		
(v) The HN sends the Transfusion Report and results of the post-transfusion blood cell count to the Blood Transfusion	BO.12	send Transfusion Report	D35	Transfusion Report

Service.		
Certification		
(a) The HCP or the CCP request a Certification.	P.4 request certification	D36 Request of Certification
(b) The FD refers the HCP to the SP for a Certification (according to competencies).	M.FD.4 refer the HCP to SP for Certification	D16 Request of Consultation
(c) The HN performs Case Management's proper actions.	S5.1.D Case management D	
(d) The HN sends a message to the patient make an appointment.	BO.8 send message to the patient	D5 Message to the Patient
(e) The patient confirms the appointment.	P.1 confirm appointment	D6 Patient Confirmation
(f) The SP or the FD makes a patient's assessment at home.	S3.3 Clinical Assessment	D12 Clinical history
(g) The SP or the FD writes the Certification.	M.11 write Certification	D37 Certification
INR Follow-up		
(a) The FD refers his patient for an INR Follow-up or it is part of the intervention plan.	M.FD.5 refer the HCP for INR Follow-up	D38 Request of INR
(b) The HN performs Case Management's proper actions.	S5.1.E Case management E	
(c) The HN schedules periodic specimen collections.	BO.7 schedule activity	D4 Daily Schedule
(d) The HN sends a message to the patient to make an appointment.	BO.8 send message to the patient	D5 Message to the Patient
	P.1 confirm appointment	D6 Patient Confirmation
(e) The Nu performs the blood collection.	N.1 Specimen Collection (blood, urine, faeces).	
(f) Results of the test are delivered to the FD or to the SP (Cardiologist) who writes the INR Report.	M.12 write INR Report	D39 INR Report
(f) FD or the SP (Cardiologist) prescribes the new anti-coagulant therapy.	S4.2 Prescription of Pharmacological Treatment	D28 Prescription of Pharmacological Treatment
S5.3. Nursing Care		
(a) The FD or PC refers the HCP for nursing care or it is part of the intervention plan.	S4.4 Prescription of nursing care	D30 Prescription of nursing care
(b) The HCP gives consent. In case of a non-compliant or non reliable HCP, the CCP gives consent.	P.3 give consent	D7 Patient Consent
(d) The HN performs Case Management's proper actions.	S5.1.C Case management C	
(e) The HN sends a message to the patient to make an appointment.	BO.8 send message to the patient	D5 Message to the Patient
(f) The patient confirms the	P.1 confirm appointment	D6 Patient

appointment.		Confirmation
(g) The Nu performs the procedure.	N.1	confirm appointment
	N.2	I.M. Injection.
	N.3	Intravenous therapy .
	N.4	Insertion, care and maintenance of peripheral intravenous infusion.
	N.5	Catheter care (insertion or removal, including perineal/penile toilet and change of drainage bag).
	N.6	Stoma maintenance, including replacement of stoma bags and wafer maintenance.
	N.7	Establishing and reviewing a stoma care program.
	N.8	Care and maintenance of tracheostomy.
	N.9	Care and maintenance of feeding tubes (nasogastric and PEG)
	N.10	Care and maintenance of urostomic tubes
	N.11	Care of analgesic pump
	N.12	Care and fitting of prosthesis, and anti-embolic stockings
	N.13	Assistance with nebulisers, metered aerosols, turbuhalers, canisters and inhalers
	N.14	Monitoring of vital signs (checking the patient's temperature, pulse, respiration, blood pressure, and pain)
	N.15	Blood sugar measurement.
	N.16	ECG
	N.17	Maintenance of skin integrity, including changing of position of a chairfast or bedfast care recipient.
	N.18	Pressure Ulcer treatment
	N.19	Treatment of other skin lesions
	N.20	Simple wound dressings
	N.21	Complex wound management
	N.22	Insulin therapy
	N.23	Suctioning airways
	N.24	Enema administration

	N.25	Training of CCP	
S5.4. Social Assistance			
(a) The SW gets in touch with the social service providers in order to verify their availability and resources for the patient's social needs	S.4	contact social service providers	D41 Social Support Request
(b) The SW coaches the patient's social network and negotiates further activities for improving the IP inside the care providers' group. [supervision]	S.5	coach social network	D42 Social Coaching Report
(c) The HCP gives consent. In case of a non-compliant or non reliable HCP, the CCP gives consent.	P.3	give consent	D7 Patient Consent
(e) The SW sends a message to the patient to make an appointment.	BO.8	send message to the patient	D5 Message to the Patient
The CCP, SO, ICG perform the assistive actions.	P.1	confirm appointment	D6 Patient Confirmation
	S.7	perform assistive actions	
S5.5. Counselling			
(a) The HCP and his CCP are interviewed (by FD, PC, HN, SW, Nu, SP, SO) about their needs connected with the HC.	BO.2	ask information	
(b) Information is given about the actual HC service supply, sanitary rules, diseases and condition management.	BO.1	provide information	D43 Information Sheet

Table 4 Procedure definition

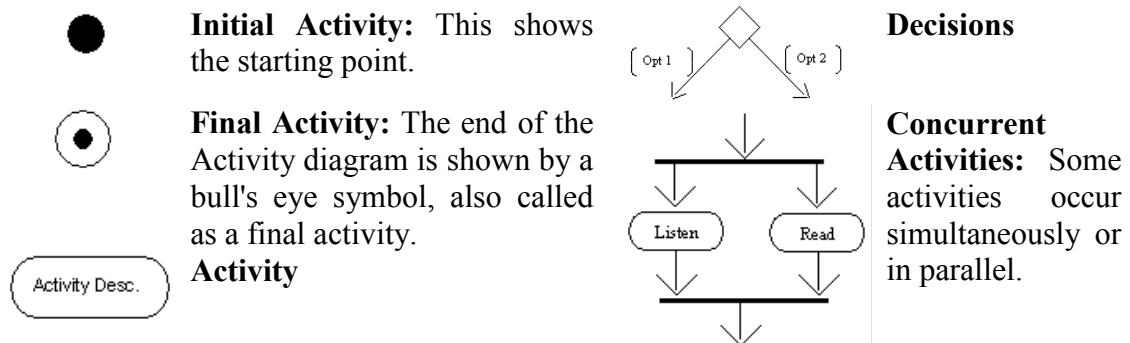
4.3 Example: Single Nursing Procedure

In an initial phase of this study, we took the *Single Nursing Procedure* presented in B.4 of the D01-1-01-rev-F as an example to explain this. In this procedure we can identify four actors: Family Doctor (FD), Physician in Charge (PC), Head Nurse (HN), and a Nurse. This actors need to consult different sources of data: the EHR, the Actor Profile Ontology, Case Profile Ontology and the Formal Intervention Plans. The actors should be able to create, modify, or consult some of this information. Each of them has different permissions over each data value. This procedure is described as:

- The FD refers his patient to the HC service for a single nursing procedure (e.g. blood collection; blood sugar test).
- The FD fills in a form to admit the patient to HC. (*K4CARE ICT*)
- The PC and HN make a pre-evaluation of the request.
- The HN sets up a waiting-list. (*K4CARE ICT*)
- The HN organizes a daily-list intervention. (*K4CARE ICT*)
- The HN (or another nurse supervisor) makes a telephone call to the patient in order to make an appointment for the home visit. (*K4CARE ICT*)

- The nurse performs the procedure.
- The patient's EHR is updated throughout the procedure (*K4CARE ICT*)

In Figure 16 we can see the activities diagram for the single nursing procedure:



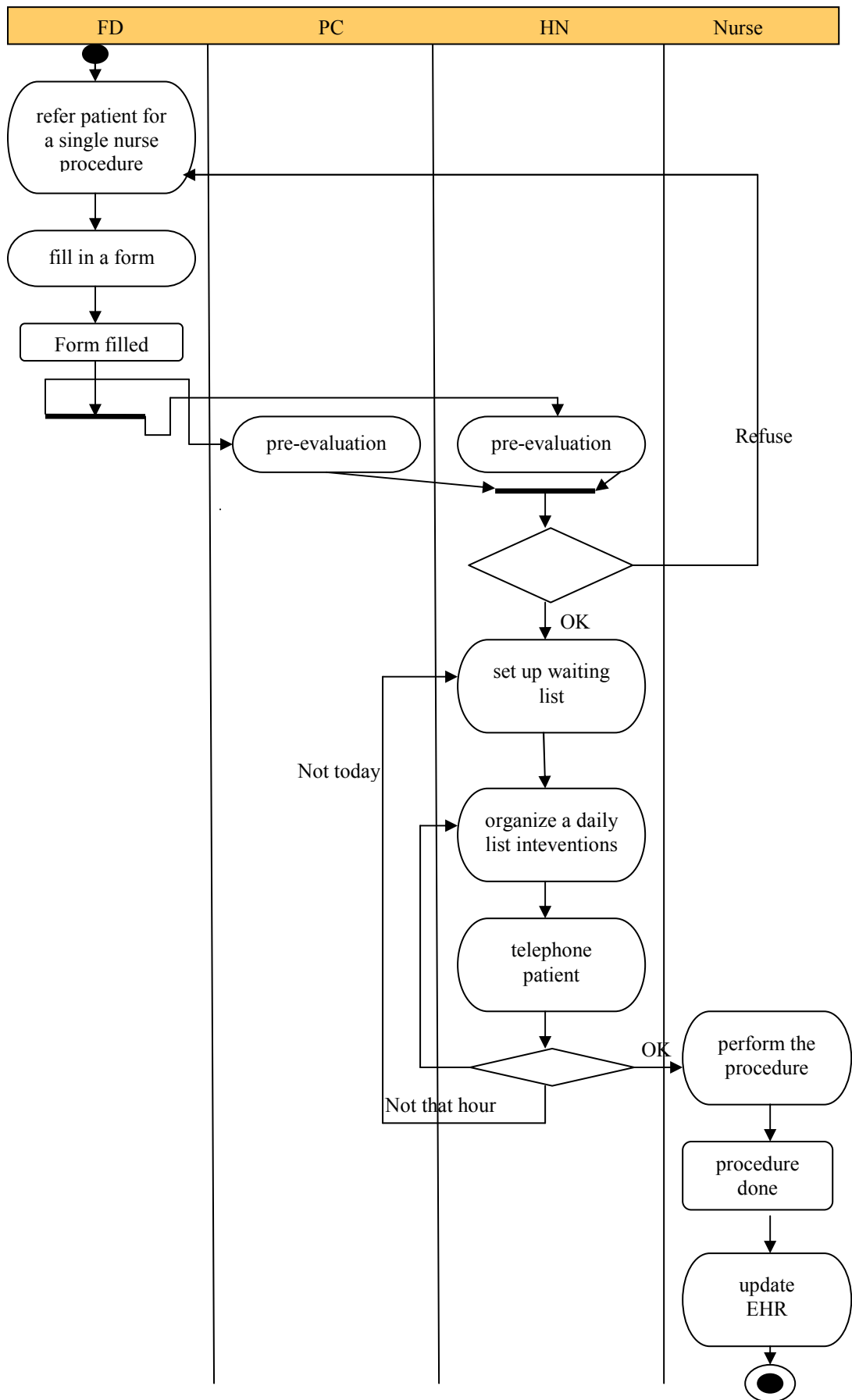


Figure 16 Sige Nursing procedure activities diagram

4.4 Solution adopted: SDA*

In section 4.2 we explained that our first step to solve the lack of control flow was construct flow diagrams. Flow diagrams should be associated to the procedures and delivered to MAS to control the performance of every procedure. The representation model of a procedure should allow represent states, actions, decisions, concurrence, the actors that permforms an action, which are the documents associated to this action and its permissions.

As said, K4Care Formal Intervention Plans were represented using the SDA* model. As a second step, we studied the possibility of adapt the SDA* to represent procedures. We found that SDA* was a model representation that supports states, decisions and actions, it supports the storage of the actors involved in each action, it supports concurrence, it controls in which moment an action has to start, end, and if it has to be repeated. For these reasons, SDA* could be adapted and be used to represents procedures. As a result SDA* has been incorporated into the K4Care system to represent procedures. That is, the control flow and actors involved in an action was solved by including this formalism to the K4Care model to encode procedures.

The SDA* doesn't supports the link between documents and actions. The solution we proposed was to store this link into the Actor Profile Ontology, which already has information about types of documents and their permissions. That is, we propose to add a new property between actions and documents that represents this connection. In Figure 17 we can see the classes Actor and Document of the Actor Profile Ontology and their properties. In blue we can see the new property *usesDocument*. The properties *isWrittenBy*, *isReadBy*, *isReadSometimesOf* in class Document are the permissions of the actors.

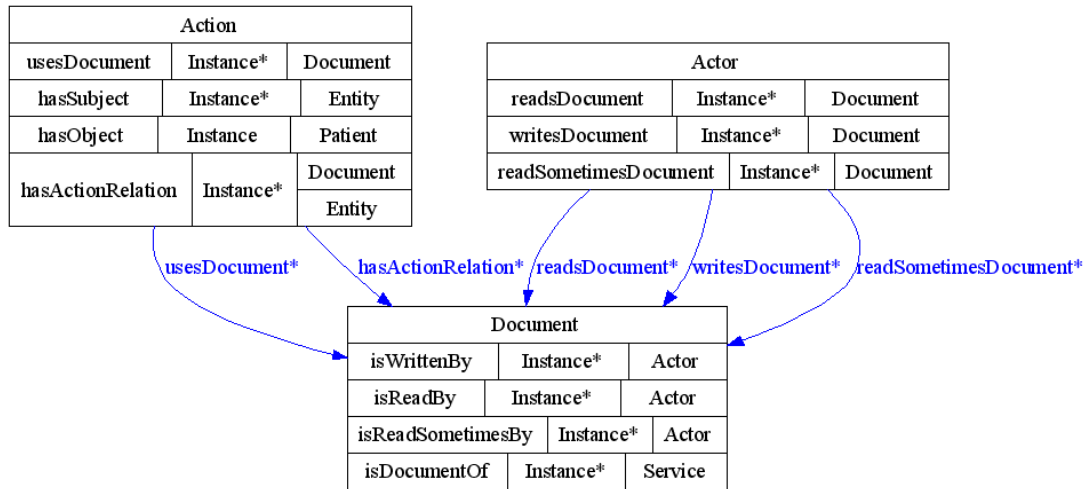


Figure 17 Actor Profile Ontology: Classes Action and Document and their properties.

5 CASE STUDY: COMPREHENSIVE ASSESSMENT

In this section a case study is used to illustrate the Data Abstraction Layer and the Data Access Interface that supports requests from agents. One of the services available (see Table 2) in the K4Care project has been selected as a case study: the Comprehensive Assessment [4].

The Comprehensive Assessment (CA) is a service to assess the condition of the patient during the first encounter, and whenever a re-evaluation is required. The CA service is devoted to detect the whole series of patients' diseases, conditions, and difficulties, from both the medical and social perspectives. It is performed at admission, at periodical or end-treatment re-evaluation time and during the evaluation of the patient condition through the time. Comprehensive Geriatric Assessment (CGA) [30, 21] served as a model for the process of assessment: it is a multidimensional process designed to assess an elderly person's functional ability, physical health, cognitive and mental health, and socio-environmental situation. A multidisciplinary comprehensive approach to geriatric assessment has evolved over the past 20 years as a way to improve the care of frail elderly patients with complex conditions. Several studies show benefits from this approach; these include greater diagnostic accuracy, improved functional and mental status, reduced mortality, decreased use of nursing homes and acute care hospitals, greater likelihood of living at home, and greater satisfaction with care.

Each of the medical services that the K4Care provides to the users (Comprehensive Assessment, Multi-Dimensional Evaluation, Request of Laboratory Analysis, etc.) follows one or more medical procedures. Each procedure is composed by a set of simple actions or calls to other *services* that must be done to successfully complete the service.

With regard to our case study, the Comprehensive Assessment, we worked together the doctors' team to identify the steps of the procedure to be followed and to provide a specification of the procedure. Table 5 shows the definition of the CA procedure and Table 6 refers to the documents that are involved in this service and the permissions for the actors that perform the CA procedure.

Comprehensive Assessment Procedure	
Code	Description
BO.03 refer the admitted patient for CA	The PC or the HN refers the admitted patient for a CA.
BO.05 assign members of EU BO.13 actor confirmation	The HN assigns the members of the EU.
BO.08 send message to the patient	The HN sends a message to the patient to make an appointment.
P.1 confirm appointment	The HCP confirms the appointment
EU.1 evaluate through scales	EU makes the patient's assessment at home according to a standardized interview (Multi-Dimensional Evaluation).
S3.3 Clinical Assessment	FD or PC performs Clinical Assessment

S3.4	Physical Examination	and Physical Assessment.
S3.8	Social Needs and Network Assessment	The SW performs the Social Needs and Social Network Assessment.
BO.01	provide information	The HCP provides the necessary information. In case of a non-compliant or non reliable HCP, the CCP provides the necessary information.
BO.06	confirm or modify waiting lists	The HN performs Case Management or Back Office proper actions
BO.07	schedule activity	

Table 5 Comprehensive Assessment Procedure

When the information in Table 5 and Table 6 is taken to design the Data Abstraction Layer, it is found that the available information contains a lot of implicit and incomplete information necessary for the design of the Data Abstraction Layer model. As said, the flow between the procedure steps has to be explicitly defined, since a procedure is not always a simple sequence of actions, but may contain loops and decisions. In addition, doctors initially provided a list of documents for the service but they did not specify in which action they are used. As we explain in section 4 doctors were required to indicate at which step the documents are used.

Comprehensive Assessment Documents			
Name	Purpose	Description	Permissions
D10	Request	Request of CA	Head Nurse, Physician in Charge: W/R
D11	Anamnesic	MDE Scales	Evaluation Unit: W/R
D12	Anamnesic	Clinical History	Physician in Charge, Family Doctor: W/R
D13	Anamnesic	Physical Examination Report	Physician in Charge, Family Doctor: W/R
D1	Request	Actor assignment	Head Nurse: W/R
D2	Authorization	Actor Confirmation	Evaluation Unit: W/R
D5	Request	Message to the patient	Head Nurse: W/R
D6	Authorization	Patient Confirmation	Patient: W/R

Table 6 Comprehensive Assessment Documents

As we have argued, we proposed to use SDA* model to represent the control flow of the Procedures of the medical services provided by the K4Care system, Formal Intervention Plans and Individual Intervention Plans. It was required to make explicit the sequence of actions.

We work together doctors to provide the information to build the SDA corresponding to the Comprehensive Assessment procedure (see Figure 18). In the figure we have indicated which documents are used in each action. In addition, notice that some actions can be done alternatively by an actor or another. The three last actions BO.01, BO.06, BO.07 of the procedures are not included in the SDA diagram. The reason of not be included is because doctors consider these actions are not part of the Comprehensive Assessment, although they are included in Deliberable01.

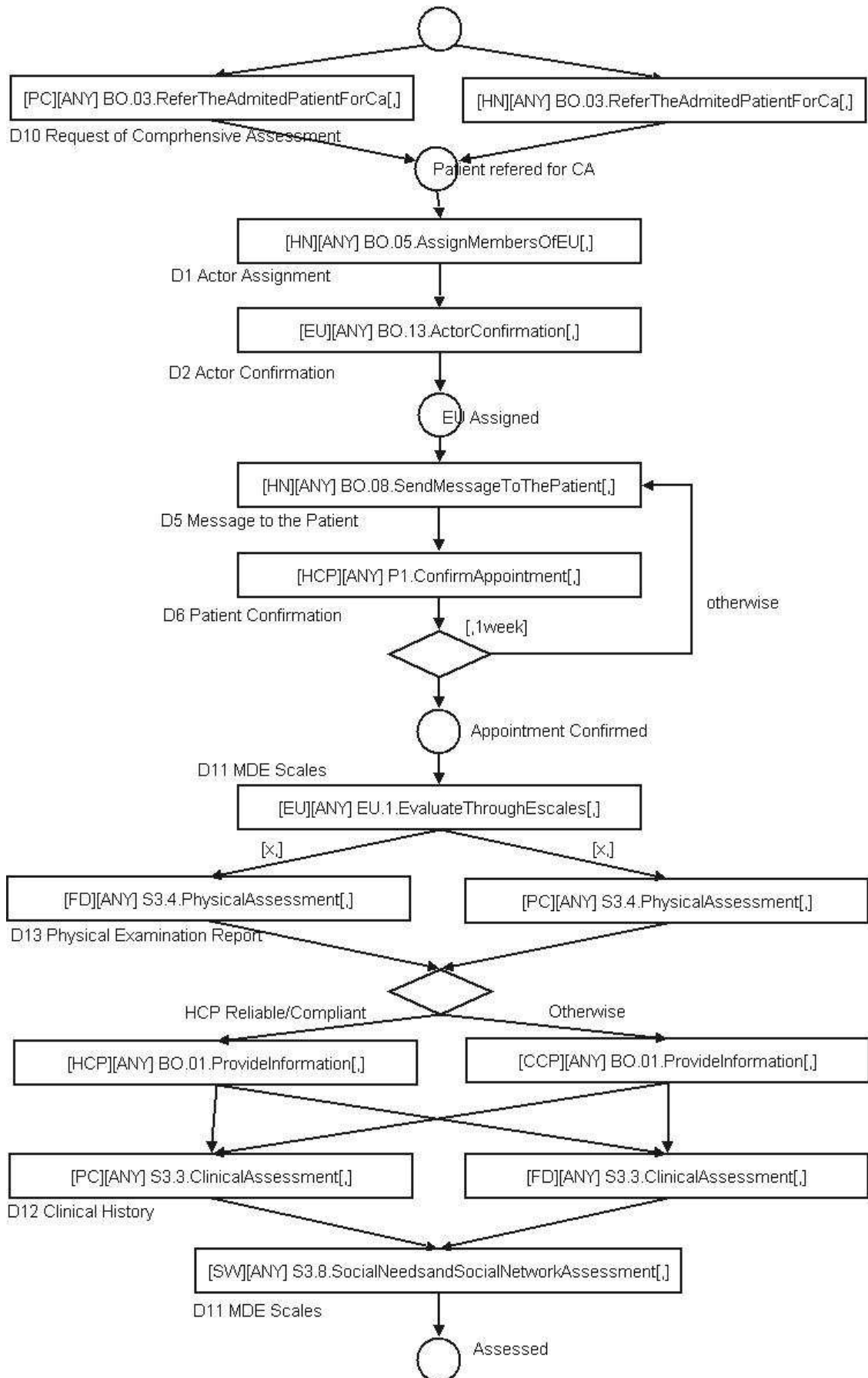


Figure 18 Comprehensive Assessment procedure in SDA*

The comprehensive assessment procedure is quite complex and many different actors are involved in it. The execution starts with action BO.03. The physician in charge (PC) or the head nurse (HN) refers a patient for a Comprehensive Assessment. Then the HN assigns the members of the evaluation unit (EU) that will do the assessment of this patient (BO.05). Then the actors who compose the EU must confirm his/her availability (BO.13). Also, the HN send a message to the patient to make an appointment (BO.08), and the patient (HCP) confirms or rejects the appointment. If the patient rejects, the HN tries to find a new appointment. When an appointment is already confirmed, the EU makes the patient's assessment at home according to a standardized interview (EU.1). Then the family doctor (FD) or the PC makes a physical assessment. This assessment implies the start of a new procedure (service S3.4). At this moment, if the patient is reliable and compliant he provides necessary information, otherwise this information is provided by the continuous care provider (CCP) (BO.01). Then a Clinical Assessment is done by the PC or the FD. This action starts a new procedure (service S3.3). Finally, the social worker (SW) performs the Social Needs and Social Network Assessment. This action also starts a new procedure (service S3.8).

6 DATA ABSTRACTION LAYER

In the K4Care model that we have presented in section 2.6.2, the agents must be able to manage data from many sources. We have also explained that each source requires the use of a different language. In the first design of the K4CARE system, the agents had to access directly to each of the different data sources. That approach has the following drawbacks:

- The agents have to read OWL files (Actor Profile Ontology and Case Profile Ontology are expressed in a formal language called OWL). That is, agents would have to parse these files and manage the high level consultations to the APO or CPO.
- The agents have to get Procedures, Formal Intervention Plan, and Individual Intervention plans (expressed in XML) from their file storage.
- The agents have to access to the data base (where is stored the administrative data of the whole K4Care set of actors, the electronic health record, and all the documents and document schemas of the patients) through SQL calls.
- Agents should know in which location the data value is stored.
- The information storage support and language is not transparent for the multi-agent system.

For these reasons, we have studied the K4care model and its limitations and we propose an extension of the model. Our proposal consists of creating an intelligent intermediate layer that implicitly knows where the knowledge is required by the agents and which is able to manage the communication requirements to the proper knowledge sources. This intermediate mediator is called *Data Abstraction Layer* (DAL). This layer permits the agents of the Multi-Agent System access to the knowledge through high level consultations (Java calls, whatever the real data representation language is). In Figure 19 we can see the intermediate layer that facilitates the access to the data. The DAL is composed by different Application Programming Interfaces (APIs) and a new element called Data Access Interface. The APIs are a set of Java methods that work as a bridge between the knowledge stored in a particular place and the rest of the system. The Data Abstraction Layer elements are the following:

- The EHR API (see section 3.1.3) provides the information contained in the EHR and some administrative data (for log-in), which are stored together in a relational database. The result of the EHR API is given in the Java K4CareStorage object.
- The SDA API provides access to the data stored in the SDA representation, for example the Formal Intervention Plans which define the guidelines to assist patients who suffer from particular ailments or diseases, Individual Intervention Plans which are FIPs adapted to the particularities of a patient or procedures which are executed to perform a service.
- The Actor Profile Ontology API and a Case Profile Ontology API have been created to consult the knowledge contained in the APO and the CPO ontologies.

These APIs, which return data through a K4CareOntology object, allow consultations to the specific knowledge contained in the APO or the CPO, such as the services that an actor can start or the types of documents contained in the EHR. The APO API and the CPO API access to these Ontologies through a OWL Wrapper, designed and implemented also inside the K4CARE project [5].

- The most important part of the Data Abstraction Layer is the Data Access Interface (DA). This element works with many different knowledge sources and translates the data to fit into the Java objects required by the multi-agent system. The Data Access interface has also an active role, it is in charge of the permissions of access to the different data sources; it prepares the forms for the data to be displayed to the browser; it combines information from different sources to give a unique answer to high-level queries, etc.

In Figure 19 we can see the K4Care model. In orange there are the parts of the model that I have designed and implemented in this Master Thesis: Data Abstraction Layer, and the APO and CPO APIs. In following sections we will explain these elements in detail.

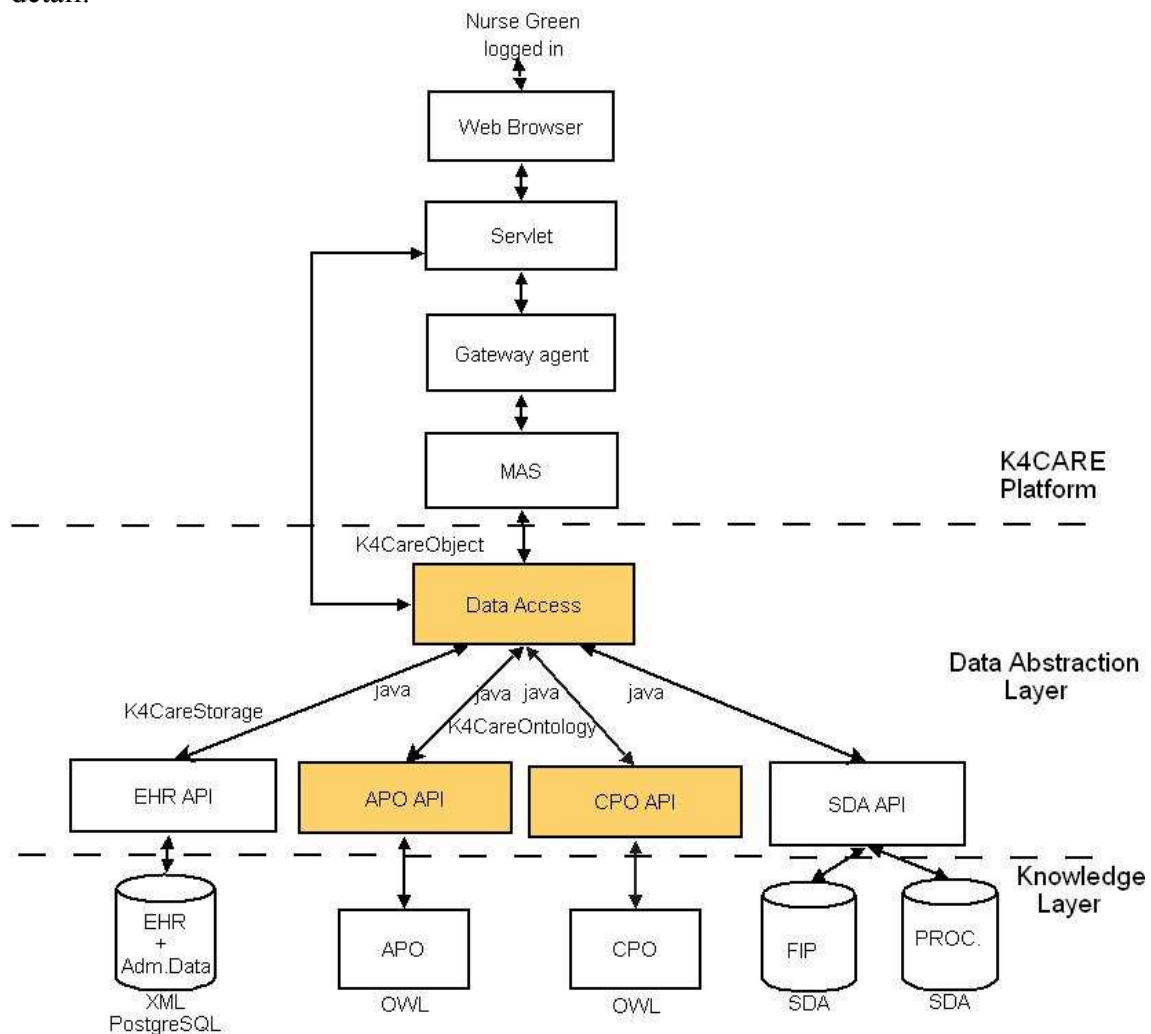


Figure 19 K4Care Model

6.1 Data Access Interface

In the K4Care model, the new layer we design, Data Abstraction Layer, is located between the Knowledge Layer and the K4Care Platform. As it has been said, the Data Abstraction Layer is composed by a set of interfaces between the knowledge (i.e. ontologies, electronic health records, procedures, individual intervention plans and formal intervention plans) and a block called Data Access.

The Data Access is an interface and a set of classes that are able to compose simple and complex queries from the petitions done by the agent, retrieves the corresponding information contained in different knowledge sources and composes an answer to the agents. It must also have an active role, it is in charge of the permissions of access to the different data sources; and it combines information from different sources to give a compound answer to complex queries, etc.

In Figure 21 we can see the flow of communication in K4Care, in red there is stated out where is located the Data Access Interface in this flow. An actor (a family doctor, social worker, etc) wants to obtain information about which procedure has to be executed, he wants to obtain the document that has to be read or written in a particular action, and so on. Data Access is in charge of provide to the actors the necessary function to perform this communication.

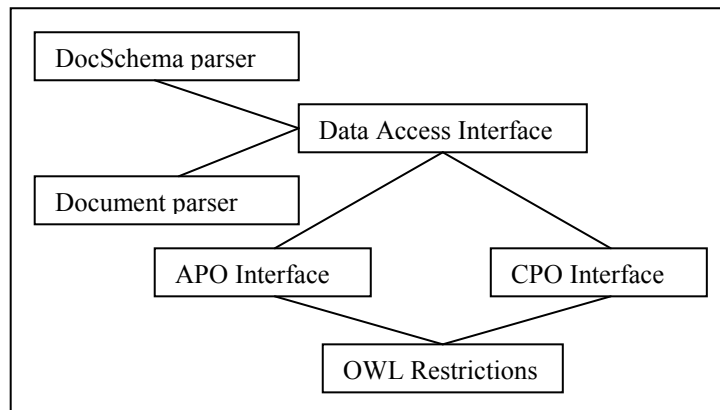


Figure 20 Main Data Abstraction Classes

6.1.1 Identification of petitions

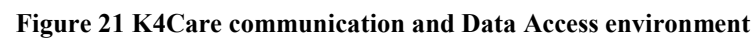
To illustrate the use of the Data Access, we have identified the petitions derived from the case study of the Comprehensive Assessment (CA) service which can be requested once an agent has entered into the system. Some functionalities of the Data Access Interface identified in this case of study are:

- First, when an agent starts, an authentication should be performed in order to establish permission policies for this agent.
- Obtain administrative information from the data base, such as the list with the roles that an actor can play. Each actor can play more than one role in different sessions, for instance an actor can play the family doctor role, and the specialist physician role.
- Provide a list of services that an actor can start when he is playing a specific role.

- When the user starts a service an agent will ask the procedure of this service and its related information (SDA flow diagram, documents associated).
- Once the procedure is started, each action is performed by an agent that sends its request. For the particular case of CA, when the procedure is started agents will ask for documents and for services (see Figure 18). For example, in action B0.03 the agent requests for the document D10. DA verifies the permissions of the actor that performs the action, in this case the Head Nurse or the Physician in Charge and gets the document. But in step 5 of the CA the agent requests for a new procedure, the procedure of the service S3.2.

From this particular case it seems that three kinds of request are involved with execution of procedures:

- The DA will verify the rights of the actors to read, or write documents.
- Provide to the agents the document forms from document schemas. These forms can be empty or they might be partially auto-completed (for example, with personal data of patients, such as identification number, name or date of birth). These values are obtained with queries to the EHR.
- Provide data about Formal Intervention Plans, Individual Intervention Plans, and Procedures.
- Provide data about, actors, diseases, symptoms, etc.



6.1.2 Data Access design

After this analysis, we have enough elements to design the Data Access Interface for the K4Care model.

The Data Access is an interface that will be instantiated by the entities that will use it. In K4Care this entities are the agents of the multi-agent system and the servlet. We have decided that the agents will communicate with Data Access except when an actor logs into the system. According to the design of the multi-agent system, an agent representing an actor starts when an authentication has been performed. For this reason, when an actor logs into the system the *servlet* directly interacts with DA to requests for that authentication (see Figure 19).

We have considered the deployment of this model to a real setting. The multi-agent system of the K4Care model is composed by a wide amount of different agents, such as the agents in charge of the execution of procedures or Formal Intervention Plans, the agents that represent family doctors, nurses, social workers, etc. For this reason, the Data Access has to be capable to attend consultations of hundreds of agents of medical centres. A scalable solution is that each agent instantiates this interface (Figure 22).

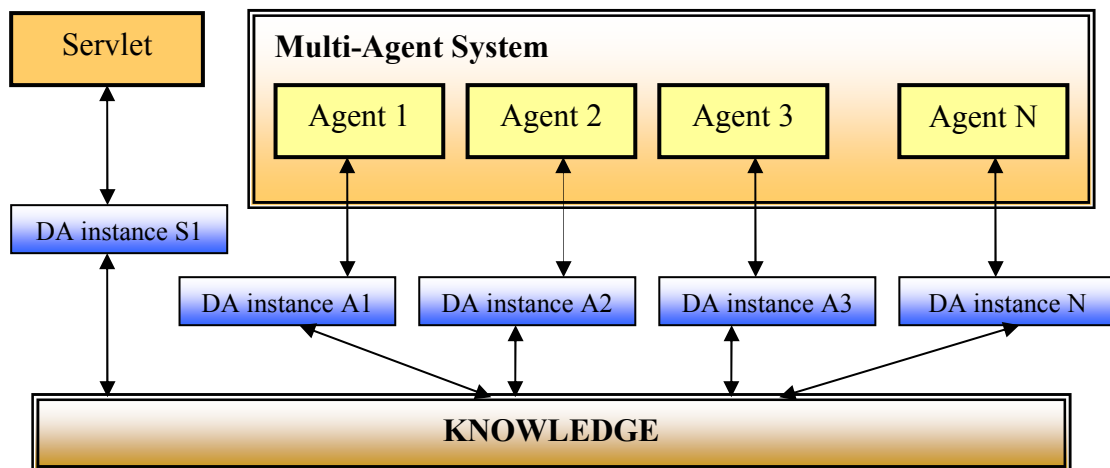


Figure 22 Data Access instances

We do not consider the possibility that the Data Access provides functions to modify the ontologies because the medical model must not be changed by the agents. The data that can be updated through this layer is the one related to the medical care of specific patients (that is, the EHR) and the administrative user's data.

Data Access as a provider of information to complete documents

When an actor has to fill in a new document, there is some information about the patient (such as the identifier, name, surname, age, etc) that appears in most of the documents

and can be easily known without requiring it to the user. The Data Access will try to facilitate the actor's work automatically providing this information.

Initially, when an agent has to write a new document, the Data Access searches the corresponding document schema, which is empty. If the agent selects the option of autocompletion, the Data Access can fill in some parts, such as the patient's name or the date and time in which the document is being created. Mainly, this data will be obtained making queries to the data base. As said, documents are written in XML, each type of document (D01,D02, etc) has a document schema. To implement this functionality, the Data Access parses the document schemas (XSD documents) and documents. Data Access could obtain the information of the elements stored in each document schema and organize it in a data structure to found, quickly, in which documents types the information is located. Data Access parses the XML documents where the relevant information is located and creates an object that includes this information. Then, the Data Access sends this new object to the agents along with the document schema. For example, in Figure 23 we can see the elements contained in the document schema D01.

```
element:
  name = assignmentId
  type = int
element:
  name = assignerActorId
  type = int
element:
  name = assignedActorId
  type = int
element:
  name = patientId
  type = int
element:
  name = assignmentDate
  type = dateTime
element:
  name = proposedAction
  type = string
```

Figure 23 Elements of D01 schema

6.1.3 Description of petitions

The Data Access is an interface written in Java. We will describe some of the functions of this interface in order to understand the functionality of the Data Access.

getDocument (int idActor, String actorRole, int idpatient)

This function returns a list of the identifiers of a document that an actor reads or writes, when he is playing a specific role for the patient identified by the identifier of the patient. This is a high level consultation, the response of it requires query the APO and the EHR. Initially, we have to identify which is the APO of the actor. Each actor has his own APO (or sub-APO, a sub-set of the APO. An APO must be instantiated in a particular physician, patient or citizen before it is applicable. This instantiation process will permit that a particular actor could introduce his or her particular vision of his role

in the K4C model. At the moment, there is not any sub-APO. Then we will consult the permissions of the actor, that is, which documents can read or write an actor playing a specific role. Then we query to the EHR the documents that the actor, playing a role, and related with a patient.

listDocuments(int idPatient, int idActor, String actorRole)

This function returns a list of Documents for a patient, and an actor (when he is playing a specific role). This is a high level consultation, the response of it requires query the APO and the EHR. Then we query to the EHR the documents that the actor, playing a role, and related with a patient. Initially, we have to identify which is the APO of the actor. Then we will consult the permissions of the actor, that is, which documents can read or write an actor playing a specific role. An finally, DA gets form the EHR the list of documents.

saveDocumentXML (org.w3c.dom.Document doc, int idActor, String docType, int idPatient, Calendar validFrom, Calendar validTo)

This function saves a XML document to the EHR. Initially, DA gets the identifier of the patient, and the actor role of the actor that saves the document. Then, DA saves the XML to the EHR, and the related information about the patient and the actor in the data base.

setEUMembers(ArrayList EUids, int idPatient, Calendar validFrom, Calendar validTo, String comment)

This function creates a new evaluation unit composed by the actors provided by the list EUids. And stores it to the data base.

getEUMembers(int idEU)

It returns the Evaluation Unit identified for the idEU.

getProcedureSDA(String service)

This method will provide the SDA for a procedure.

getFIPSDA(String fip)

This method will provide the SDA for FIPs and IIPs.

validateUser (String login, String password)

This methods is used by the servlet, it validates the user in the K4Care system.

getActorRoleName (int idActorRole)

This method gets the all the roles that an actor can play.

getPatientsId()

It returns all the patients.

getActorId(String actName)

It returns all the professional actors.

getDocTypes()

It returns the documents schemas.

getDocIds()

It returns all the documents.

canReadSometimes(String actorRole, String documentType)

Data Access consults to the APO if an actor playing an specific role can read an specific document.

permissions (String actor, String typename)

Data Access consults to the APO if an actor playing an specific role can write an specific document.

getRoleByDoc(int idDoc)

This method gets the role of the actors that had written a document.

getProcedure(String service)

It returns the procedure for that service.

getServices(String actor)

It returns services that an actor may start

getSDA (String procedure)

It returns the SDA of a procedure. This information is stored in the APO.

getActionDocs(String action)

It returns the actions contained in a procedure

getDocuments(String actor)

It returns documents that can be managed by an actor.

getCanBeCauseOf(String disease)

It return the syndromes that can be caused by a disease from the CPO. A disease can be the cause of n syndromes.

getCanBeExpressionOf(String syndrome)

It returns the diseases that can be the expression of a syndrome form the CPO. A syndrome can be expression of n diseases.

getIntervention (String disease)

It returns the intervention that can be done when a patient suffers a disease or syndrome or social issue.

public String getFIP(String ds)

It returns the FIP of a disease or a syndrome.

6.2 Access to the Actor Profile Ontology

This interface allows high level consultations to the APO. At the implementation level, the ontology provides a **K4CareOntology** object, which represents a single point access

to the APO ontology. Following the same model than the K4CareStorage object, explained in section 3.1.3 and used for the access to the EHR.

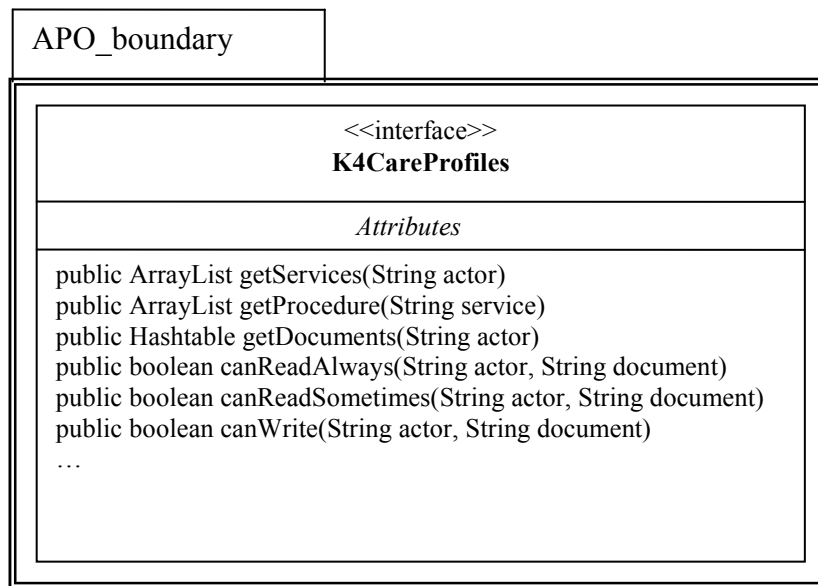


Figure 24 APO interface

As an example in Figure 24, we can see some methods of this interface. These methods allow agents to obtain the services that an actor, playing a specific role, can initiate, the procedure SDA identifier (in order to be able to go to the Procedures storage and retrieve it to execute it), the documents associated to a service and finally the permissions of the actors in order to read or write a document.

For example, the function `getDocuments(String actor)` returns a list with all documents types that an actor (i.e. family doctor, head nurse, physician in charge, etc.) can read, can read in special circumstances and the ones that he can write.

6.3 Access to the Case Profile Ontology

Following the same idea, we have developed an interface that allows high level consultations to the CPO (Figure 25).

At the implementation level, the ontology provides a **K4CareOntology** object, which represents a single point access to the CPO ontology and following the same model than the rest of the data sources of the K4Care project.

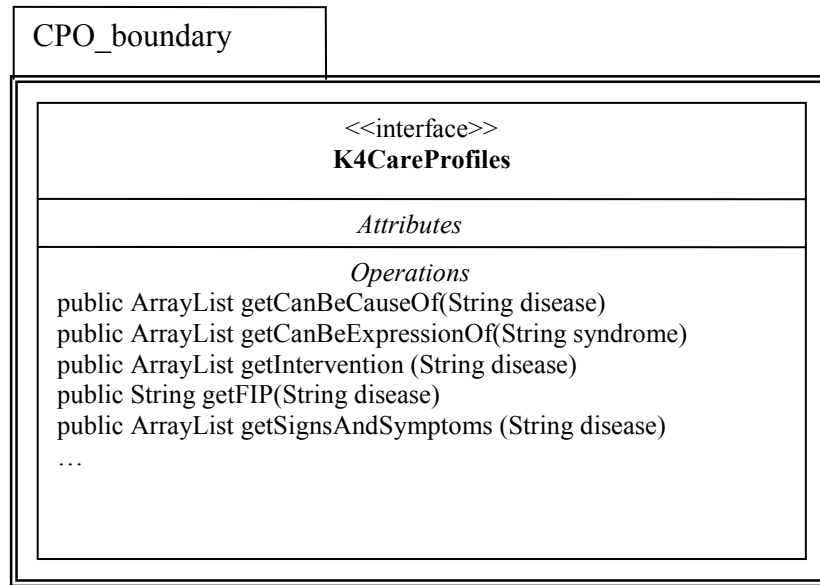


Figure 25 CPO Interface

As an example in Figure 25 there are listed some methods of this interface. These methods allow agents to obtain the syndromes that can be caused by a disease, the diseases that can be the expression of a syndrome, the intervention that professional actors must to apply to cure the patients that suffers an specific disease or syndrome, get the FIP of specific disease or syndrome, or get the signs and symptoms of a disease, a syndrome or a social issue.

For example, the function `getCanBeCauseOf(String disease)` returns a list with all the syndromes that can be caused by a disease.

6.4 Testing the Data Access with the Comprehensive Assessment procedure

In this section we will test the prototype implemented of the Data Access Interface and the APO, CPO, and EHR interfaces through the case study that we used to illustrate the Data Abstraction Layer.

It is implemented a graphical tool to test the Data Abstraction Layer. This tool is divided in two parts, on a hand, it simulates the execution of the Comprehensive Assessment (CA) procedure and the petitions of the different actors/agents involved in the procedure to the Data Access Interface. On the other hand, we provide concrete requests to the Data Access Interface because Comprehensive Assessment does not use all the functionalities of the Data Access Interface.

Comprehensive Assessment procedure

A graphical tool to simulate the CA procedure and the requests that agents has been created. When we start the tool, we must select the patient that will be assessed. In this case we have selected the patient=11257278. Now, we can start the execution simulation of the CA procedure.

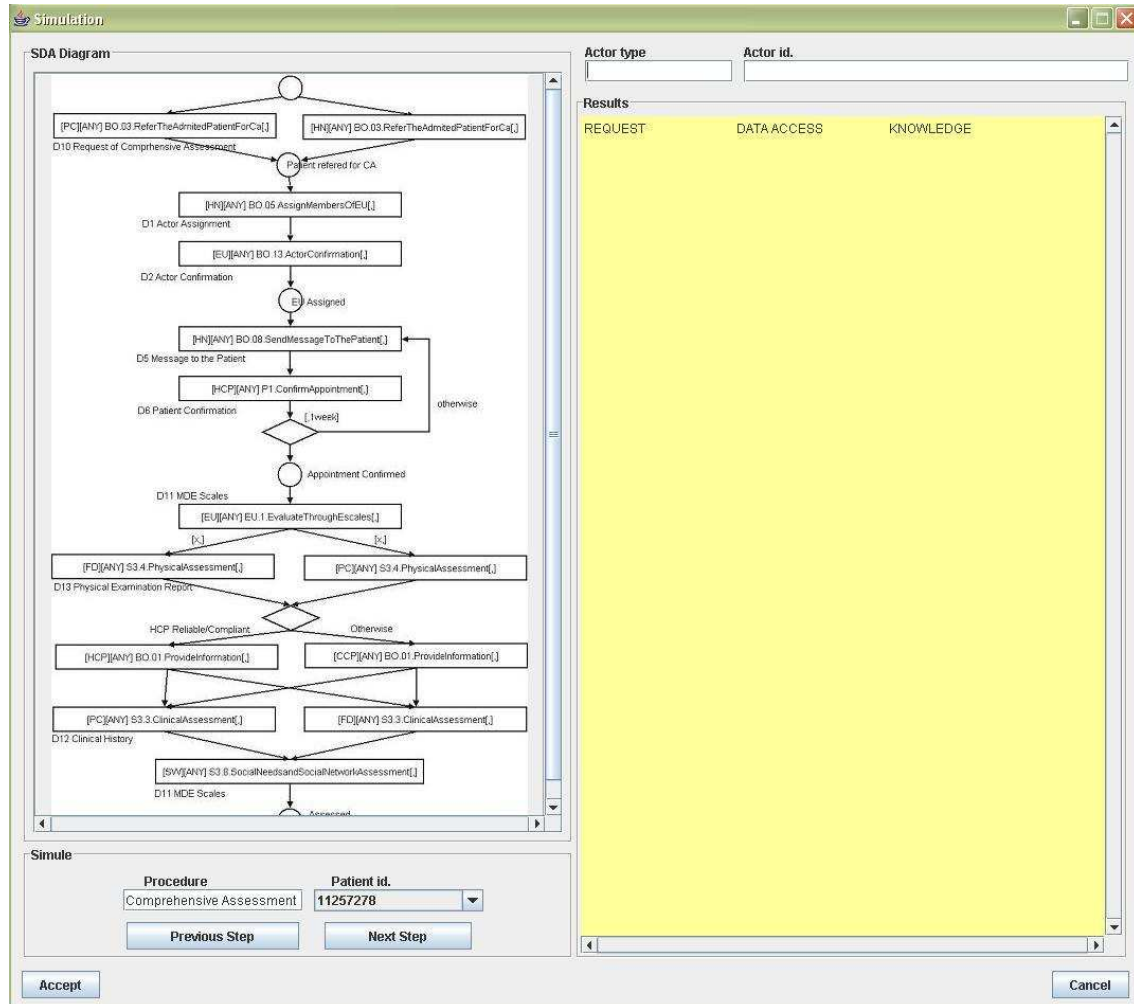


Figure 26 Start window

The first step of the procedure is referring the patient for a Comprehensive Assessment (action BO.03). Thus, the physician in charge (PC) or the head nurse (HN) refers a patient for a Comprehensive Assessment.

We suppose that this action is done by any PC. In this case the PC with id=11257265. Action BO.03 has linked the document D10 (Request of Comprehensive Assessment). The corresponding agent requests the document schema of document D10 to the Data Access Interface (DA). Initially, the DA requests the APO (thought the APO API) if an actor, playing the physician in charge role, has writing permission on D10. We obtain an affirmative response. Then, the DA ask to the EHR for the D10 schema, in this case the response is that this schema don't exist because, as said, at the moment only some document schemas are defined (in concrete, D01, D02, D11, D12, D13, D19, D20).

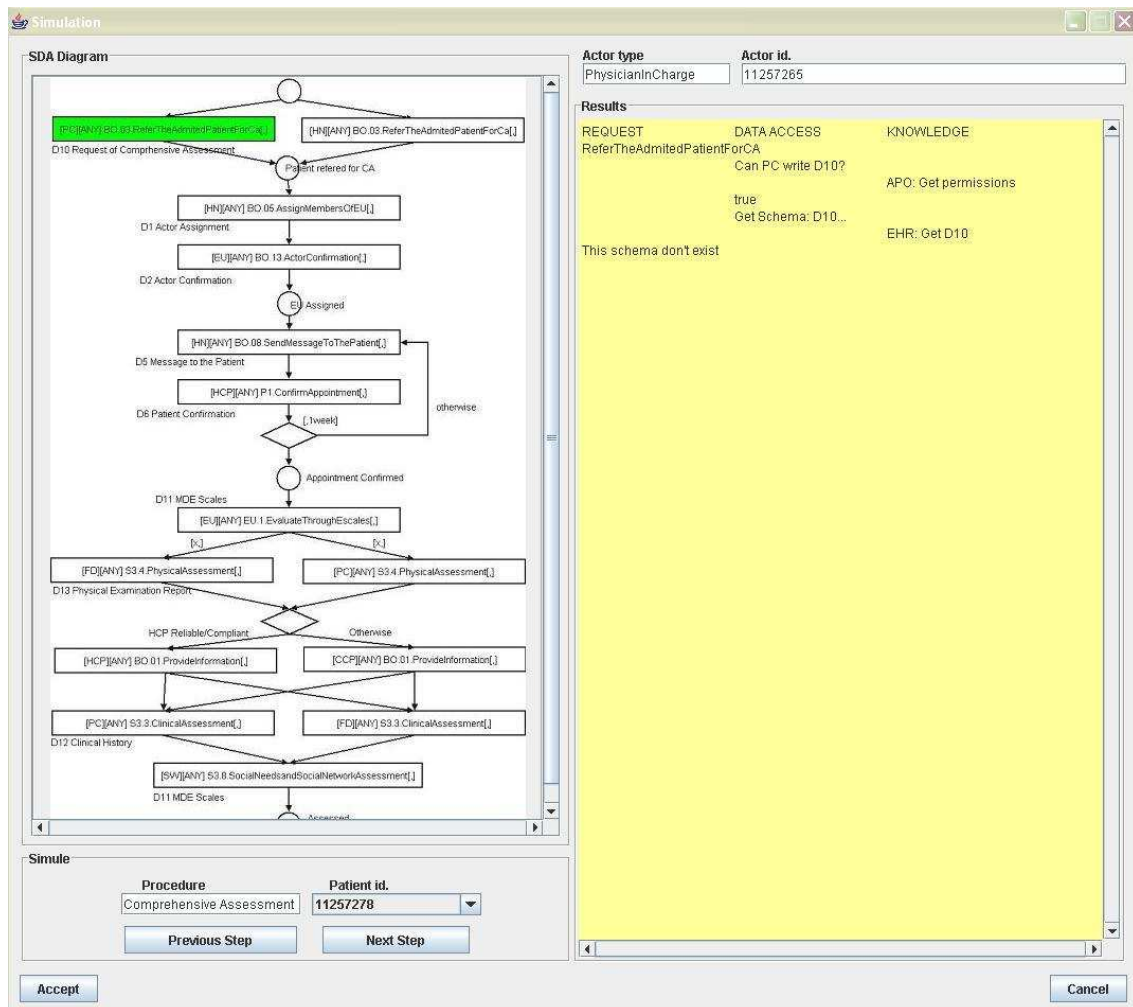


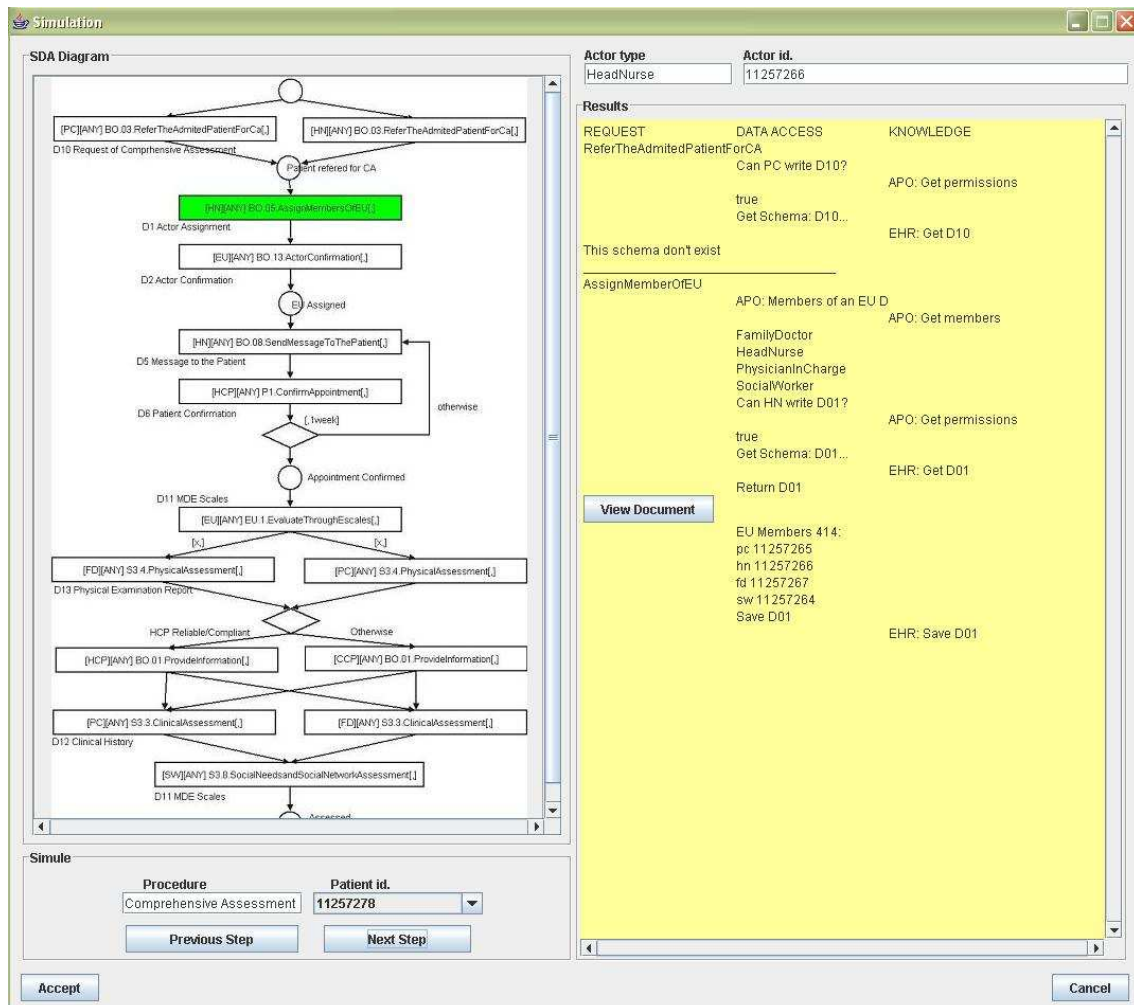
Figure 27 BO.03.ReferTheAdmittedPatientForCa

In the next step, the HN assigns the members of the evaluation unit (EU) that will perform the assessment of this patient (BO.05). The DA asks to the APO who the members of an EU are. The response provided by the APO API is that an EU is composed by a physician in charge, a head nurse, a family doctor, and a social worker. We can assign the members of the EU (really, the nurse would make this assignation).



Figure 28 HN assigns members of an EU

We suppose that this action is done by any HN. In this case the HN with id=11257266. Action BO.05 has linked the document D01 (Actor Assignment). The corresponding agent requests the document schema of document D01 to the Data Access Interface. Initially, the DA requests the APO if an actor, playing the head nurse role, has writing permission on D01. We obtain an affirmative response.



Then, the DA asks to the EHR for the D01 schema and we obtain it. Pressing the “view document” button a window is opened, and we can see the D01 schema. In this moment, the nurse would write this document and then she would save it. At the moment, we will save the same document schema instead of the new document created by the head nurse because this task is out of our scope and because for testing the petition to save a document we only need a well formatted XML document.

In addition, the DA saves the new Evaluation Unit into the database (table GroupOfActors). The identifier of the new EU is 414, and the members of the EU are: a physician in charge with id=11257265, a head nurse with id=11257266, a family doctor with id=11257267 and a social worker with id=11257264.



Figure 29 Document schema. D01

When an actor has to fill in a new document, there is some information that appears in most documents. For example, in the document schema of D01 we have the following elements:

element:
 name = assignmentId
 type = int
 element:
 name = assignerActorId
 type = int
 element:
 name = assignedActorId
 type = int
 element:
 name = patientId
 type = int
 element:
 name = assignmentDate
 type = dateTime
 element:
 name = proposedAction
 type = string

We can provide to the agent an object with some information that appears in most documents. The DA parses the document or documents and extracts all the relevant information. For example if we parse another document of type D01 we obtain the following information and select the information relevant and provide it to the agent along with the document schema.

The assignment id.: 12
 The assigner actor id.: 11257266
 The assigned actor id: 11257267
 The patient id is: 11257278
 The assignment date is: 2001-10-26T21:32:52

The proposed action is: Comprehensive Assessment

Next, the actors who compose the EU must confirm his/her availability (BO.13 Actor Confirmation). Each actor confirms through document D02. For these reason, DA is in charge of ask to APO if a PC, HN, FD, and SW can write D02. If true, the DA obtains the document schema of document D02 from the EHR and send to the agents that represent the actors. The actors write a new D02 document, and their agents ask to the DA to save the document. Then, the DA saves the document to the EHR.

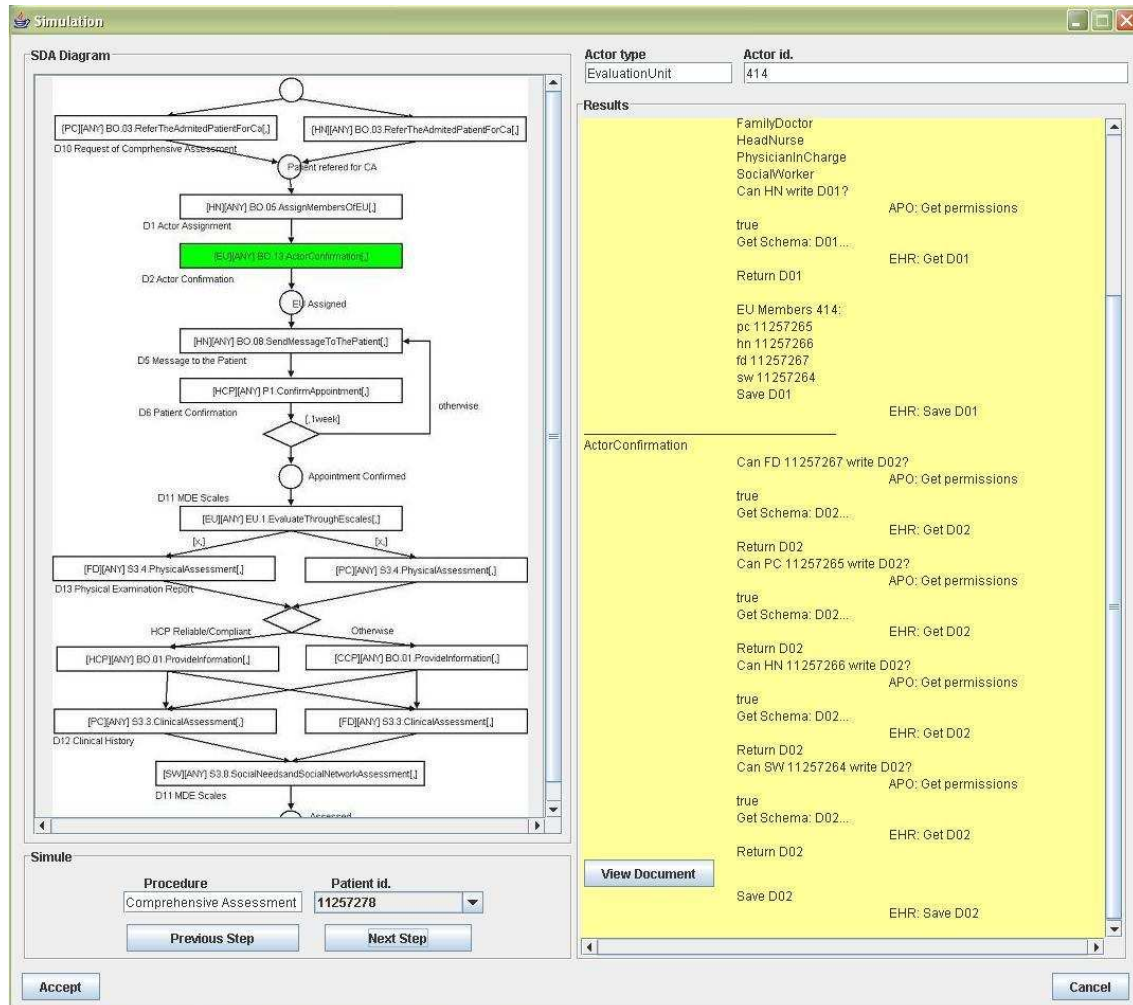


Figure 30 BO.13 Actor Confirmation

In the following steps, the HN sends a message to the patient to make an appointment (action BO.08. SendMessageToThePatient), and the patient (HCP) confirms or rejects the appointment. If the patient rejects, the HN tries to find a new appointment. When an appointment is already confirmed, the EU makes the patient's assessment at home according to a standardized interview (EU.1.EvaluateThroughScales).

Then, the family doctor (FD) or the PC makes a physical assessment. We suppose that this action is done by the PC (id=11257265). But, this assessment implies the start of a new procedure (service S3.4 Physical Assessment). The agent in charge of execute SDAs requests the new procedure to the DA. DA will ask to the APO for this service to found the procedure. In the APO there will be stored the file names where procedures

are stored. Actually, this attribute is empty. Then, DA obtains the file from procedure storage. We can see the service S3.4 pressing the "View procedure" button.

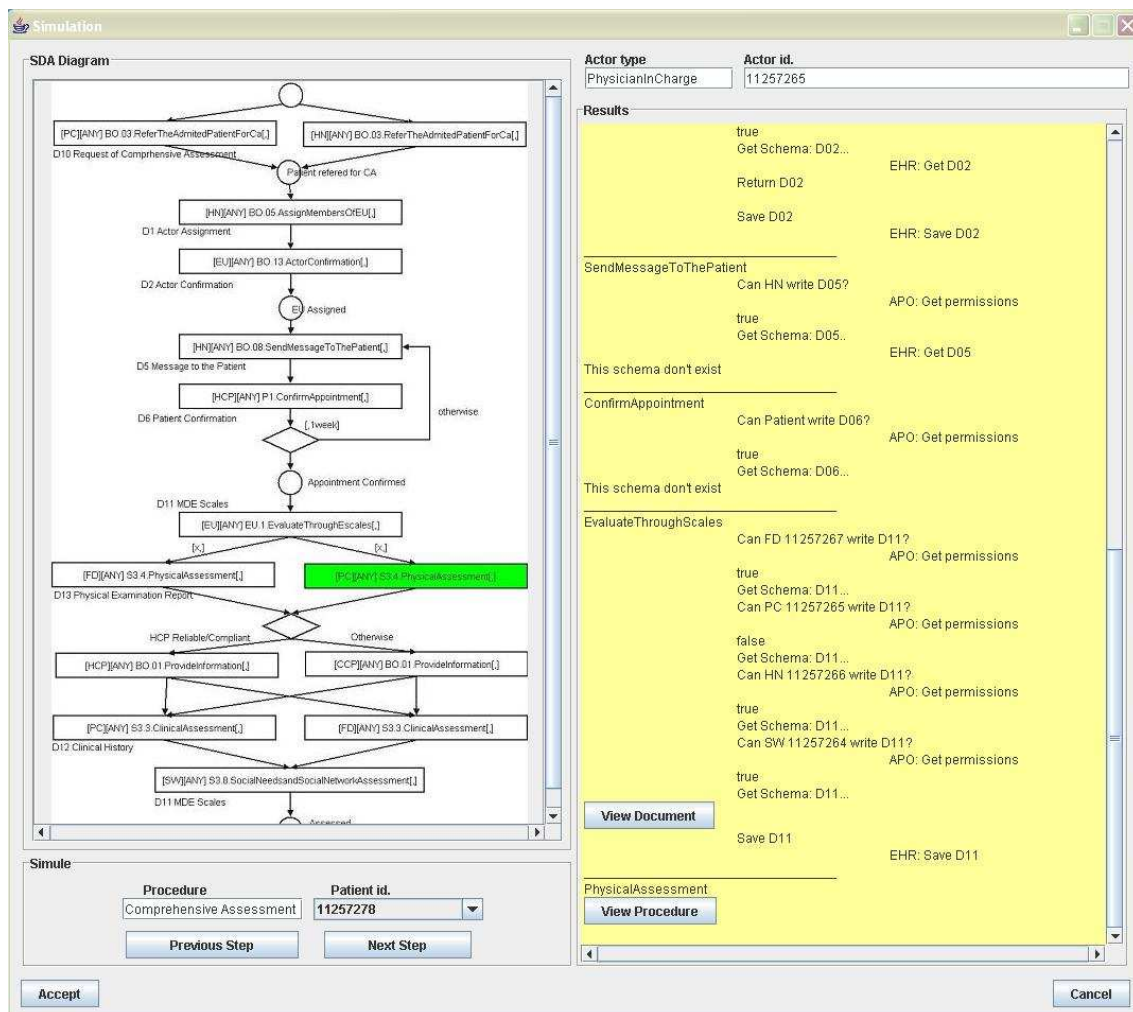


Figure 31 S3.4 Physical Assessment

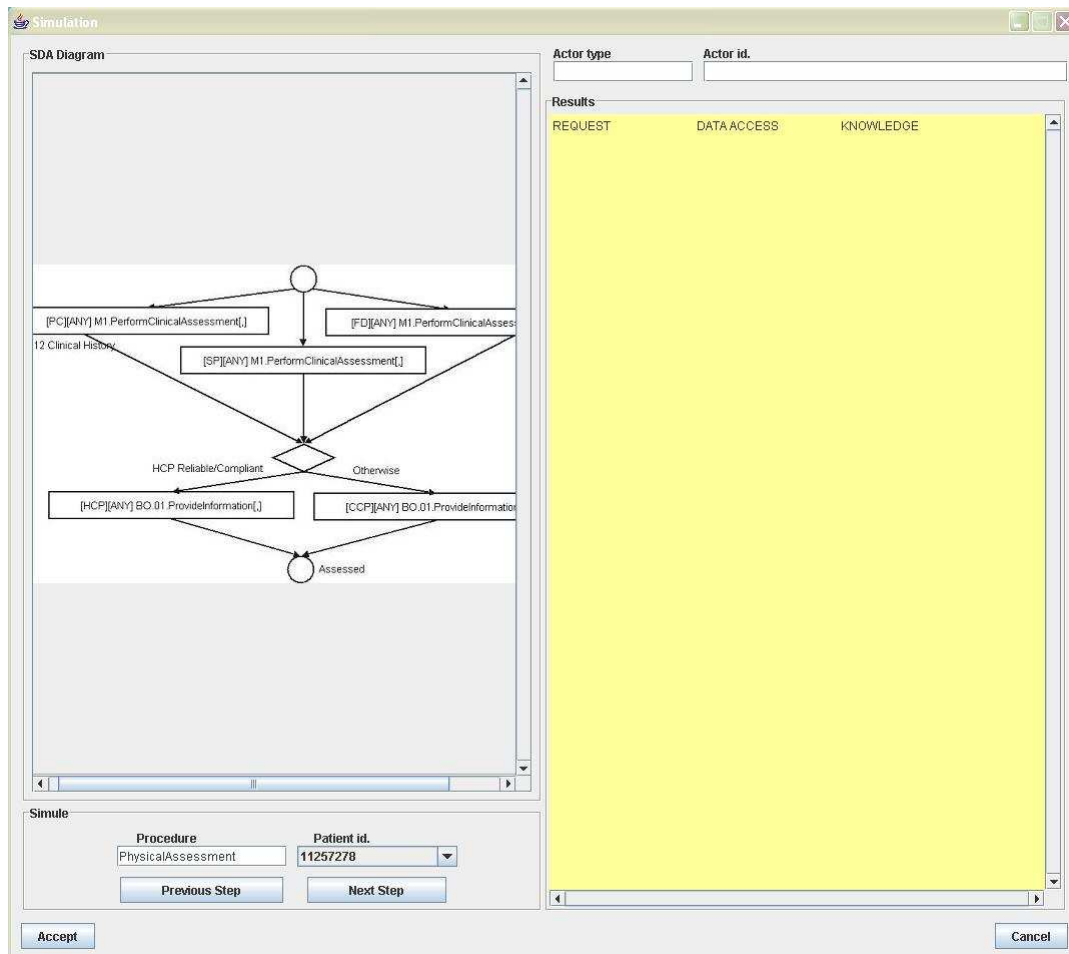


Figure 32 Physical Assesment procedure

At this moment, if the patient is reliable and compliant he provides necessary information, otherwise this information is provided by the continuous care provider (CCP) (BO.01 Provide Information). Then a Clinical Assessment is done by the PC or the FD. This action starts a new procedure (service S3.3. Clinical Assessment). Finally, the social worker (SW) performs the Social Needs and Social Network Assessment. This action also starts a new procedure (service S3.8.Social Needs and Social Network Assessment).

Simple request to the Data Access Interface

With this tool we also can do specific request to the Data Access Interface. There are multiple requests that we can do to the Data Access Interface. We could obtain knowledge of the EHR, the CPO or the APO. In this section we only put some examples.

Test Functions

Functionalities

Function: `getFIPSDA(StringName)`

Patient id.: 11257271 Doc. id.: 920

Actor id.: 11257247 Doc. type: D13

Role: FamilyDoctor

Information

REQUEST	DATA ACCESS	KNOWLEDGE

Apply

Figure 33 Test functions window

Test 1

For example, we can ask the DA for a Formal Intervention Plan (FIP). The tool shows the SDA diagram of the FIP and the text file of this sda.

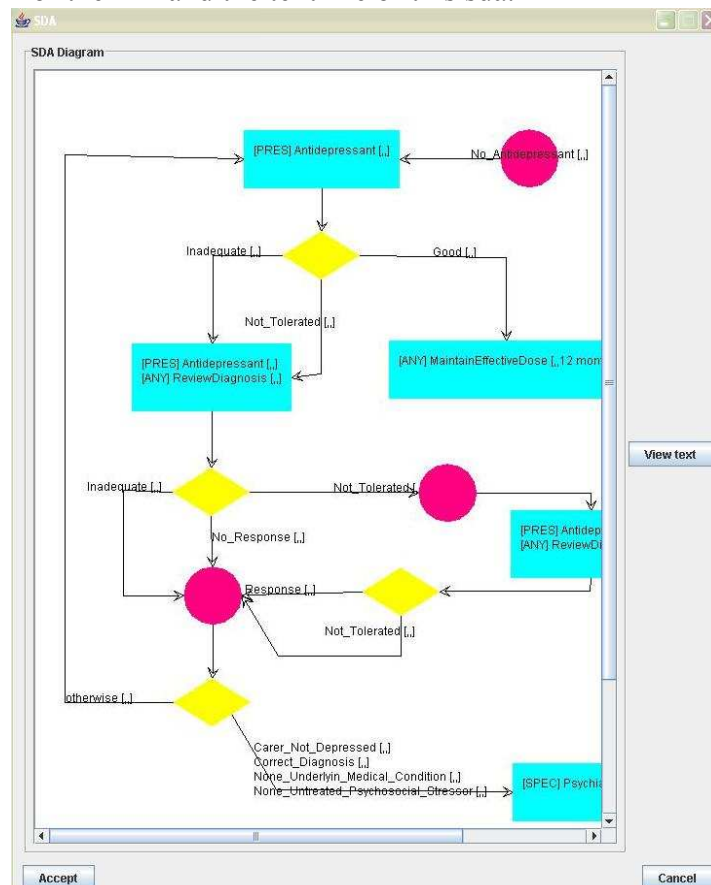


Figure 34 SDA diagram The use of Antidepressant Medication in the Elderly

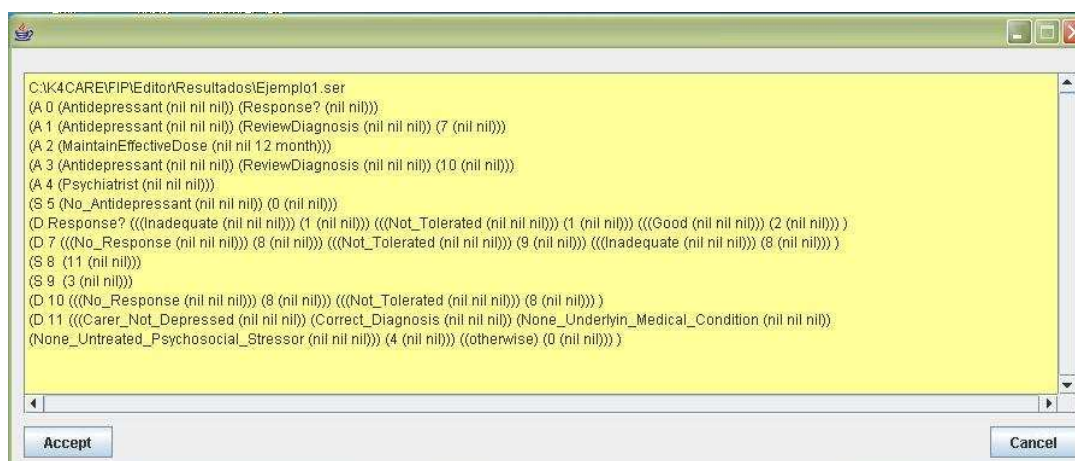


Figure 35 SDA text The use of Antidepressant Medication in the Elderly

Test 2

In this example, the head nurse asks the DA for the document with id=920, of the patient patient=11257278.

Initially, the DA asks to the EHR which is the type of this document. DA obtains that the document 920 is a D01 Actor Assignment document. Then, the DA asks to the APO if a head nurse can read this type of documents. If the response is true the DA verifies that this specific head nurse can read document 920 of the patient 11257278. When DA verifies all this information provides the document 920 to the head nurse.



Figure 36 Document 920 . D01 Actor Assignment

Test 3

In this example we consult which diseases can be expression of a syndrome. DA asks to the CPO for the Syl-CognitiveImpairmentSyndrome. The results are:

M07-Delirium
M08-Dementia
M09-Depression
M13-IatrogenicCognitiveImpairment

Test 4

In this example, we consult the services that an actor can take part. DA asks to the APO in which services a family doctor takes part.

P2PMessages
BrochureConsultation
PatientRecordOverview
WaitingList
GuideLineConsultation
FIPOverview
PharmacologicalTherapyHandbook
BestPracticeHandbook
DatabaseQueries-Services
DatabaseQueries-Clinical
IndividualSchedulingOverview
HCPAdmission
HCRequest
PrescriptionOfAssistiveDevices
PrescriptionOfPharmacologicalTreatment
PrescriptionOfNon-PharmacologicalTreatment
PrescriptionOfNursingCare
NursingCare
BloodGasAnalysis
BloodTransfusion
INRFollow-up
Consultation
Multi-DimensionalEvaluation
RequestOfDiagnosticExamination
RequestOfLaboratoryAnalysis

7 CONTRIBUTIONS AND PUBLICATIONS

The work done in this master thesis is placed in the central part of the K4Care architecture. It is the connection between the agents that provide the medical services and the knowledge layer. For this reason I have had to be aware of the whole project decisions and work in coordination with several teams. More precisely, I have needed to know in detail all knowledge sources (the know-how, and the know-what of the project), the representation of these different kinds of sources and its codification, and the functionality of the agent platform.

The two main contributions of this work are:

- To detect that there was not enough information for the procedures representation because the available information contained a lot of implicit and incomplete information necessary for the design of the procedures. I identified all the information to be formalized in order to build a K4Care procedure and propose a solution. The solution proposed was use the SDA* model.
- To detect that agents had to be able to manage data from many sources and using different languages (ontologies are written in OWL, intervention plans in XML and SDA*, and documents are written in XML and are stored in a relational data-base. The communication between the agents and the information system was difficult and inefficient in the initial architecture. To solve it, we proposed the creation of an intermediate layer that helps to manage this communication, which is called Data Abstraction Layer. Design this layer (Data Abstraction Layer is composed by different APIs, Data Access Interface, APO API, CPO API and SDA API) and implement a prototype.

I have also been in charge of the Electronic Health Records in Tarragona. I have worked as a nexus between URV and CVUT (CVUT designs and implements the relational database) and MTA SZTAKI (MTA SZTAKI defines the XML documents of the electronic health record). In this line, I have contributed proposing improvements in the Electronic Health Records and the data base. For example, in the K4Care model actors can be grouped in an Evaluation Unit. Each Evaluation Unit has assigned one or more patients. Our proposal was to create a new array in the data base (*GroupOfActors*) and its relations to represent this case (see Figure 9). I also proposed to extend the array *Administrative Data* to identify the actors in the system (adding attributes such identifiers, login, password).

7.1 Publications

Batet, M., Valls, A., Gibert, K., Survey of Electronic Health Records Standards. Research Report DEIM-RR-06-004, Dept. of Computer Engineering and Maths, Universitat Rovira i Virgili, Tarragona, Spain (2006)

Batet, M., Valls, A., Gibert, K., The Data Abstraction Layer as knowledge provider for a medical multi-agent system. 11th International Conference on Artificial Intelligence in Medicine, Workshop From Knowledge to Global Care, Amsterdam (2007)

Batet, M., Valls, A., Gibert, K., Estudi sobre els historials clínics electrònics. Research Report DEIO DR2007/4, Departament d'Estadística i Investigació Operativa. Universitat Politècnica de Catalunya, Barcelona, Spain (2007) .

Batet, M., Valls, A., Gibert, K., The SDA as a model for flow control in K4Care. Research Report, Departament D'Estadística i Investigació Operativa Universitat Politècnica de Catalunya, Barcelona, Spain (2007) (in press).

8 CONCLUSIONS AND FUTURE WORK

The fact of adding an intermediate layer to the K4Care model and the creation of the Data Access has provided a series of improvements and advantages to the model: the model is best structured; there is independence between layers; the different codifications or languages of the knowledge are transparent for the multi-agent system; and the multi-agent system will be able to make complex petitions involving information stored in many sources. In short, agents do not need to know how the Knowledge Layer is implemented.

The study done to solve the problem of the access to the knowledge has contributed with other improvements to the model. For example, the need of making explicit the relations between actions and documents, or the need of having a representation for the flow of the actions into the service procedures (proposing to use the SDA model).

Finally, the development of specific application interfaces for the different types of data sources is now being finished. Formal Intervention Plans and Procedures are represented using SDA*. Initially SDAs was written in LISP, now its designers are working to encode the SDAs in XML. For this reason, at the moment, there is not a SDA interface in the Data Abstraction Layer.

Currently Data Access Interface is working in K4Care system, but it can be transferred to any other medical system that organizes the information following the K4Care information model. Also, transfer to more general medical systems with other EHRs or ontologies structures is really easy if the APIs maintain the same offer of methods. This generalization only requires the reimplementation of the internal queries that APIs send to the corresponding information source.

At this moment, each agent makes an instance of the Data Access Interface. As a future work, it would be interesting to identify which functions are used for each type of agents (there are not yet a clear specification of this agents), and then generate different interfaces depending on the agent. With this personalisation, agents will only instantiate the functions that they will use.

It would be interesting to extract more information of the XML documents to complete some sections of new documents. Now we are limited to the specification of only seven of forty-three documents and we don't have a global view of the information contained into the documents and the sections or attributes repeated.

We, also, will work improving the Data Access with the new petitions of information that will be requested from the developers of the multi-agent system.

I would like to thank to Aida Valls and Karina Gibert for managing this project. In addition, I would like to thank Fabio Campana and David Riaño to help me to represent the Comprehensive Assessment procedure, and finally, to my colleagues in the K4Care project in Tarragona for their inestimable support.

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10 ANNEX A: USER MANUAL

In this annex we will provide a user manual for the tool used to test the Data Abstraction Layer.

A graphical tool to simulate the CA procedure and its request is made. The main window is composed by the procedure diagram on the left, under the SDA diagram there are the name of the procedure, and a list where we can select the patient to be assessed. On the right, we can found, for each action of the procedure, the actor type and actor identifier that performs the action and an informative panel.

When we start the tool, we must select the patient that will be assessed. Next, we can start the simulation pressing the "Next Step" button. (the "Previous Step" button allows to go backwards)

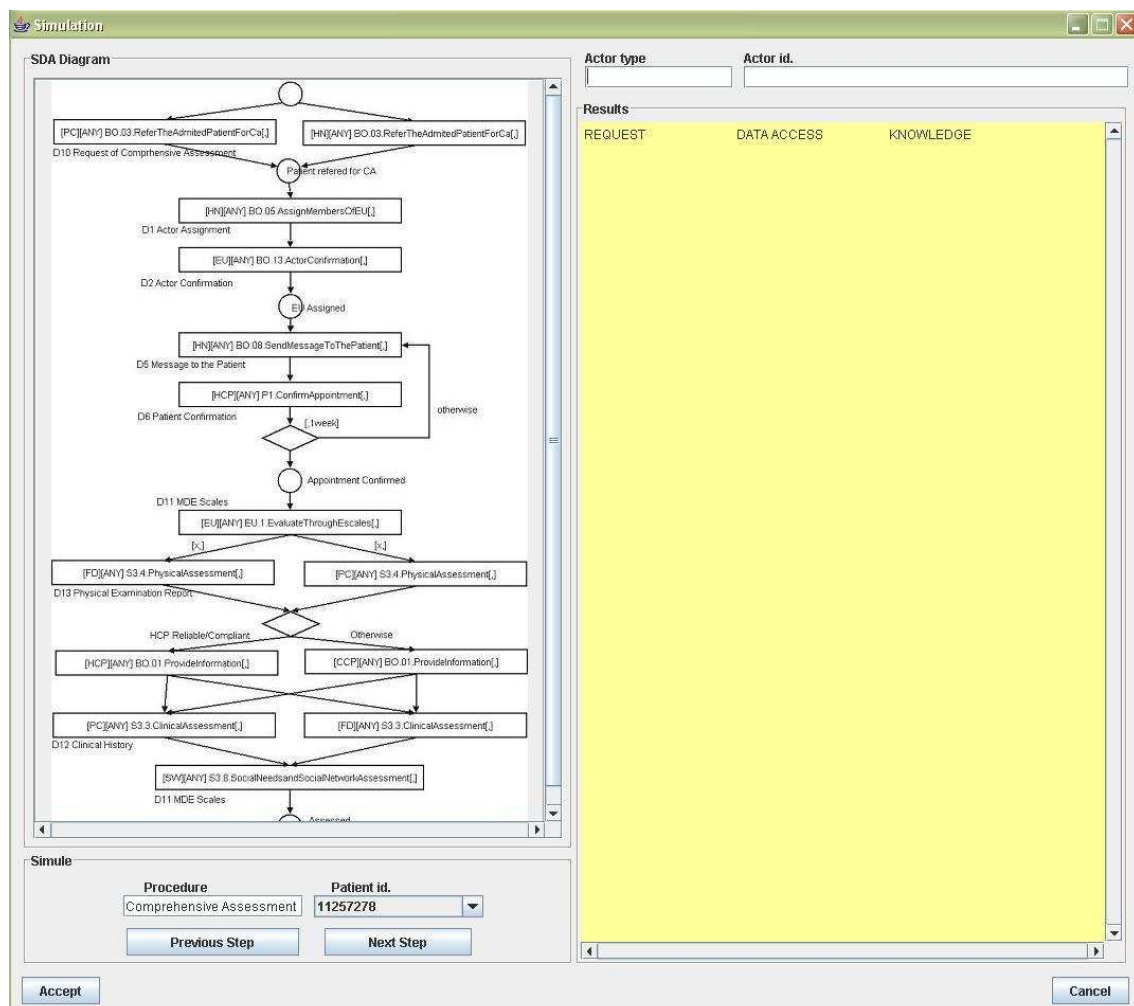


Figure 37 Start window

View a document

When the Data Access asks for a document or a document schema to the EHR, the tool provides the button “View document”. This button opens a new window that shows the XML document.

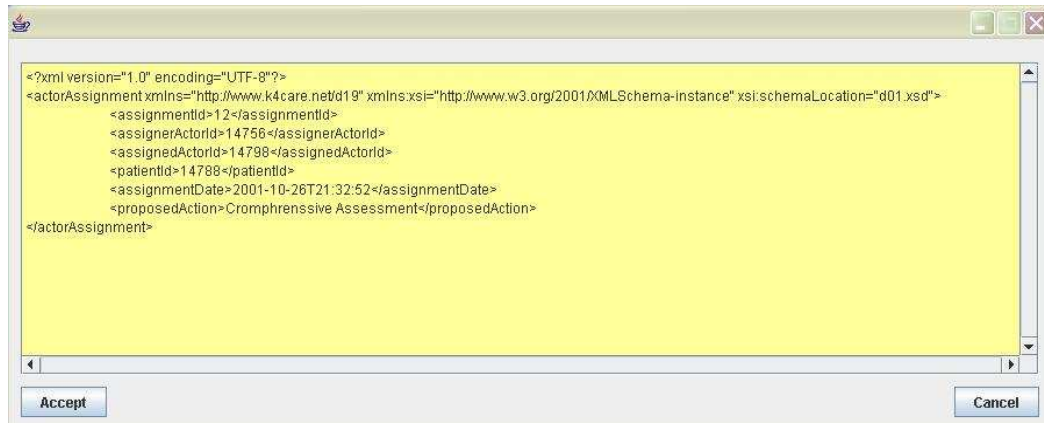


Figure 38 Document window

View a procedure

When the Data Access asks for a procedure, the tool provides the button “View procedure”. This button opens a new window that shows the procedure representation. (see Figure 37)

With this tool we also can do specific request to the Data Access Interface. We can select a specific request for the list “Function”. Then, we have to select its parameters and press the button “Apply”. The results of the different functions provided to test the Data Access are showed in the “Information” panel or if they are documents in a new document window.

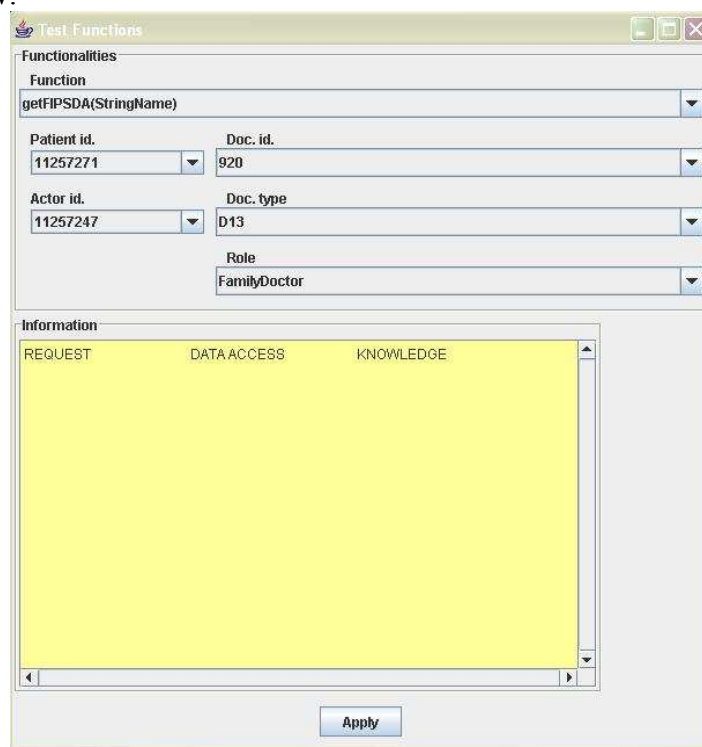


Figure 39 Functions window

View a procedure

When we ask for a Formal Information Plan, a new window is showed. We can see the text file of this FIP pressing the button “View text”.

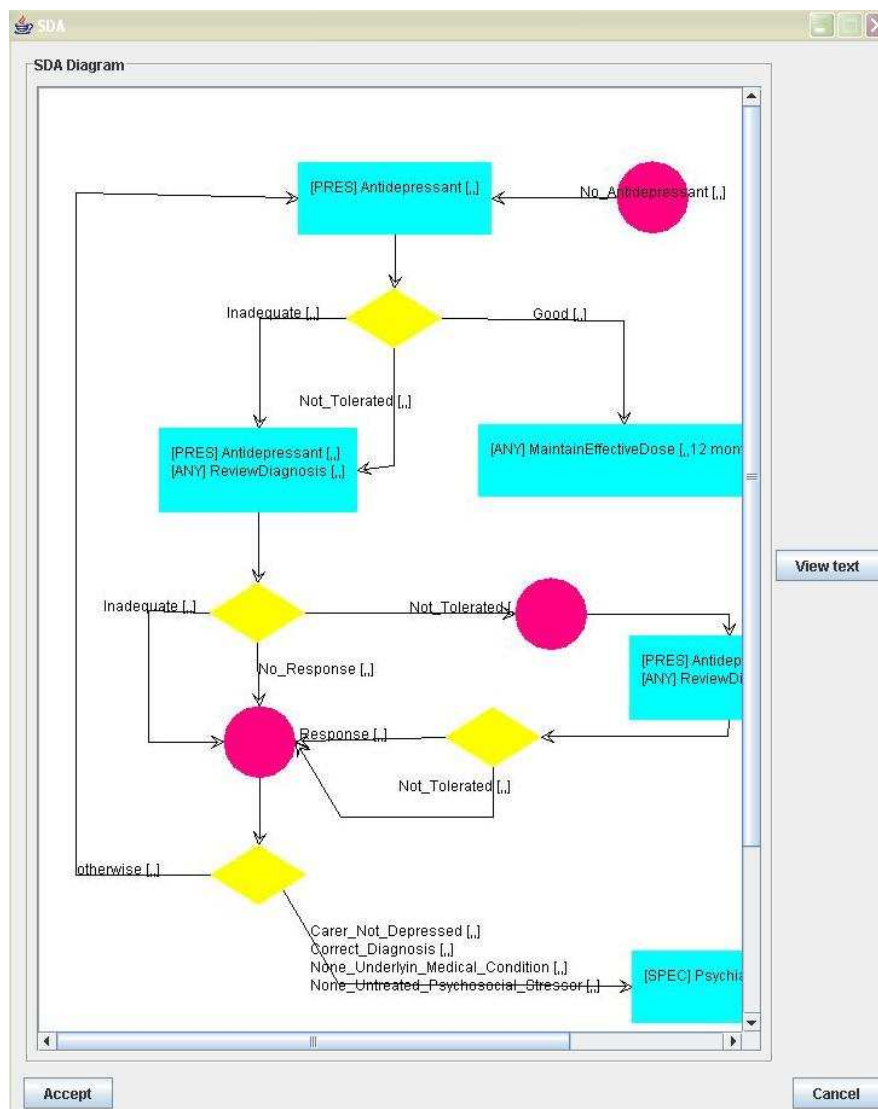


Figure 40 SDA window