Supporting the Continuity of Home Care and the Bidirectional Exchange of Data among Various Points of Care by Semantically Annotated Web Services

Maria Botsivaly and Basile Spyropoulos

***Abstract*—In this paper we report, first, the conceptualization and initial design of a system that creates a structured subset of data, concerning the most relevant facts about a patient's healthcare, organized and transportable, in order to be employed during the post-discharge homecare period, enabling simultaneously the planning and the optimal documentation of the provided homecare. Second, we present the actual development and implementation of the system according to the ASTM Continuity of Care Record (CCR) Specification. Finally, we present the implementation of a semantic-web-based system, which aims to facilitate the exchange of Clinical Information among various points of care, and we also present a solution that provides for the shared understanding of Medical Data between diverge information systems, and overcomes, both, the problems of incompatible formats in messages and of the use of diverse vocabularies.**

***Index Terms*—Home care, continuity of care record, semantically annotated Web services, data exchange among various points of care.**

I. Introduction

IT is highly anticipated that the continuous evolution of Information Technology during the last decades, in combination with the increase of mean life expectance and the hospital care cost avalanche, will eventually alter the way that health care is going to be delivered, and a significant proportion of health care will be provided in the near future in outpatient, community and homecare schemas. Nevertheless, as we move towards to this decentralized model, well argued concerns are raising about the fragmentation of patient's relevant information and the discontinuity in the delivered care [1]. Furthermore, especially in transitions from hospital to homecare, crucial questions emerge concerning the way this specific kind of care will be medically supervised and financially reimbursed.

It is generally expected that the Electronic Health Record will facilitate and simplify the exchange of information between different care providers and agencies, improving the quality and continuity of care. Nevertheless, a number of questions arise concerning the scope and the level of detail of information that should be exchanged when a patient is transmitted to a different care provider, especially in the case of transition from hospital to homecare. ASTM, an American National Standards Institute (ANSI) standard development organization, has recently approved the E2369-05, Standard Specification for Continuity of Care Record (CCR) [2]. CCR is intended to assure at least a minimum standard of health information transportability when a patient is discharged, referred or transferred, fostering thus and improving continuity in care.

In this article we report, first, the conceptualization and initial design of a system that creates a structured subset of data, concerning the most relevant facts about a patient's healthcare, organized and transportable, in order to be employed during the post-discharge homecare period, enabling simultaneously the planning and the optimal documentation of the provided homecare, and second, we present the actual development and implementation of the system according to the ASTM-CCR Specification.

Finally, an additional purpose of this study is the implementation of a semantic-web-based system, which aims to facilitate the exchange of Clinical Information among various points of care, and the presentation of a solution that provides for the shared understanding of Medical Data between diverge information systems, and overcomes, both, the problems of incompatible formats in messages and of the use of diverse vocabularies.

II. The Developed Continuity of Care Record

The CCR could be described as a proposed standard for an electronic form for patient transfer, referral, and discharge. Rather than a complete patient record, the CCR is designed to

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provide a snapshot in time containing the pertinent clinical, demographic, and administrative data for a specific patient. It is a way to create flexible documents that contain the most relevant core clinical information about a patient, and to send these electronically from one provider to another or to provide them directly to patients.

The CCR consists of three core components, the header, the body and the footer, each one consisting by a number of sections, covering the most important aspects of a patient's health condition. The sections consisting the CCR include: Patient and provider information; Insurance information; Patient's health status (allergies and other alerts, medications, medical equipment / external medical devices used by the patient, immunizations, vital signs, results, and recent procedures); Recent care provided and Recommendations for future care (care plan).

The CCR is designed to be technology and vendor neutral for maximum applicability. It must be developed on the extensible markup language (XML) platform in order to offer multiple options for its presentation, modification, and transmission. Through XML, CCR can be prepared, transmitted, and viewed in a browser, in an HL7 - CDA compliant document, in a secure email and in any XML-enabled application. The widespread use of the CCR will improve continuity of patient care, enhance patient safety, reduce medical errors, reduce costs, enhance communication and exchange of health information and standardize patient care information across healthcare providers.

It is actually anticipated that CCR will facilitate and stimulate more rapid EHR development, as an essential and simple building block.

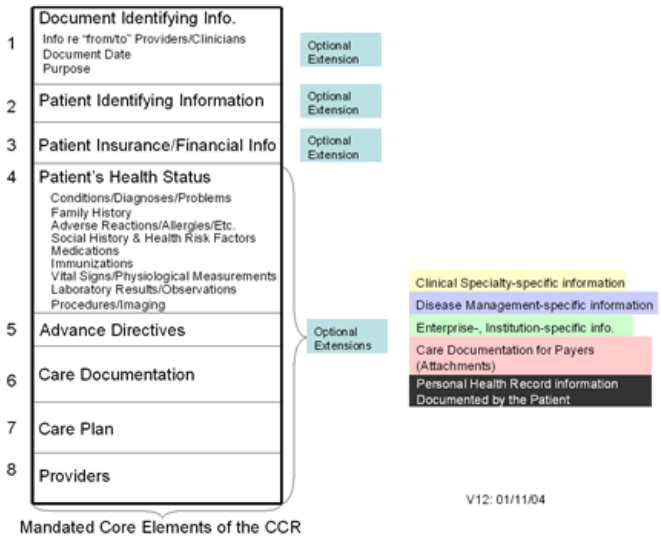

Fig. 1. Core elements of the CCR [3].

The developed system consists of two modules. The first module is responsible for the creation of a typical CCR that contains the appropriate demographic and administrative data, as well as the relevant clinical information, while the second module is responsible for the creation of a homecare plan which will be included in the Care Plan section of the CCR. The system is intended to be used upon the transition of a patient from hospital to homecare, although the first module alone could actually be used in any case of transition or referral.

The typical–CCR module can either collect the necessary data from an already installed EHR system or allow the user to enter the data manually by filling special forms. In any case, the user decides which parts of the patient's medical record (electronic or paper) are the most significant ones or are the necessary ones for the description of the current health status of the patient and should be included in the CCR.

The second module is responsible for the creation of the homecare plan by creating a structured subset of data, containing the diagnostic, monitoring, treatment, and nursing activities that should be employed during the post-discharge home-care period. The actual flow diagram of the developed system is illustrated in Figure 2. The developed model allows for every Hospital Department or Medical/Nursing group, to individually assign an appropriate set of homecare activities to specific diagnoses codes that are coded according to Diagnosis Related Group (DRG) codification.

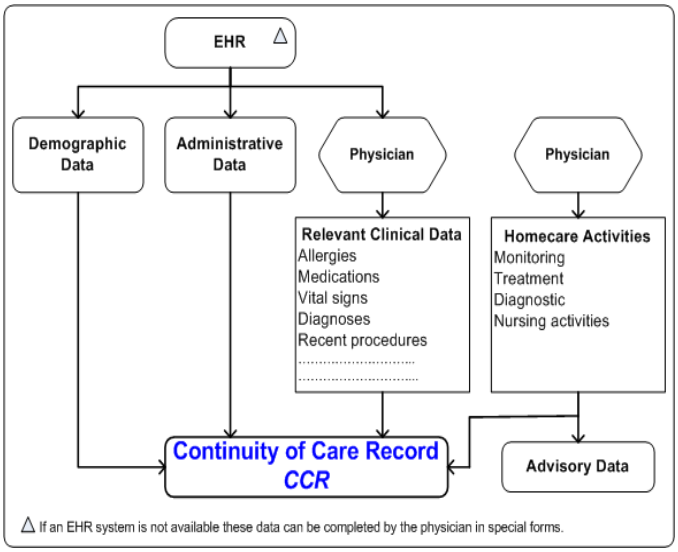

Fig. 2. Flow-Chart of the developed system.

These activity sets consist of diagnostic, monitoring and treatment activities that can be actually performed in home-environment, together with an appropriate nursing – activity treatment plan. These profiles of home-care activities are custom-made and every user, i.e. every physician responsible for discharging a patient from hospital, is actually allowed to set up his own profiles.

During the formation of these profiles the user can attach to each activity a set of nominal fees. This set of fees consists firstly of the official Insurance Agencies reimbursement amount, and, secondly, by a currently valid financial rate. This later is estimated by a software tool that we have already developed and allows for a rational approximation of the effective mean cost for several elementary medical activities, over different medical specialties [4], [5]. Thus, the developed system ignites, when relevant, the corresponding revision of an implicitly associated latent financial record that allows for an approximation of the individual case-cost.

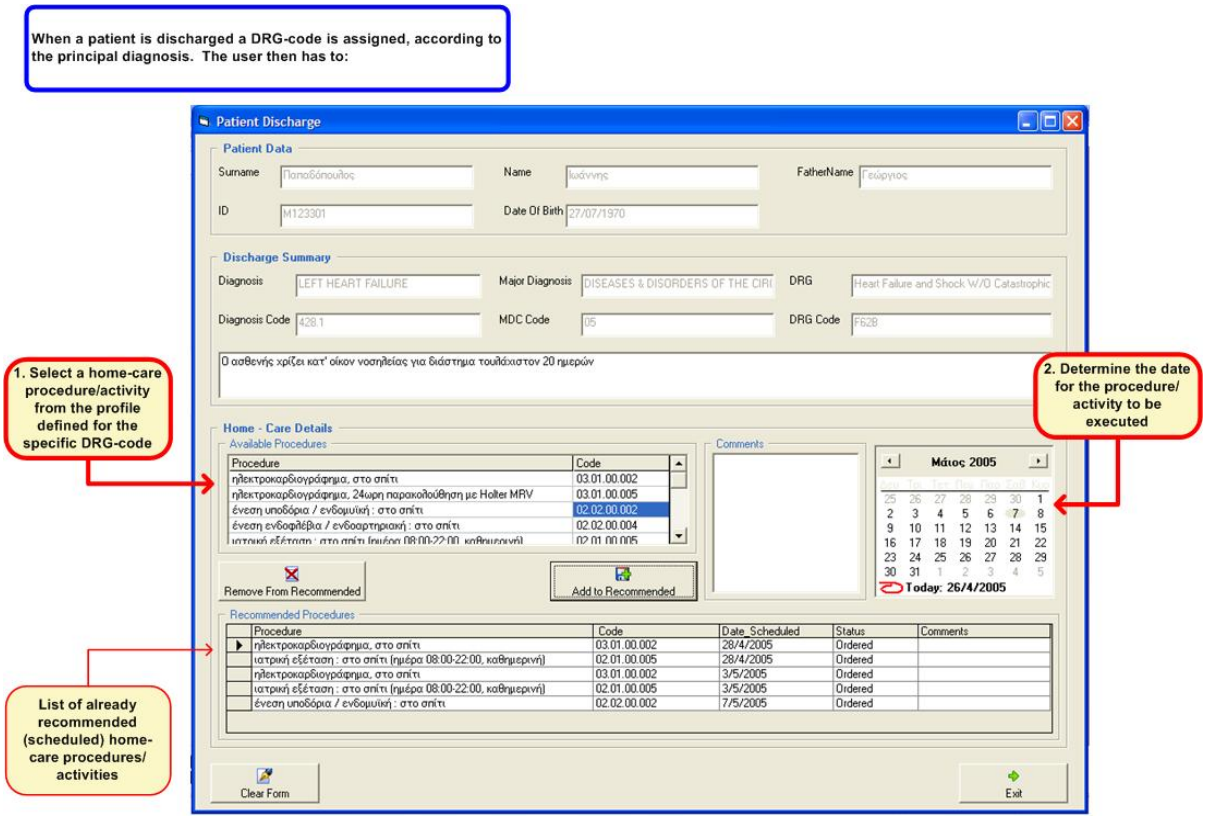

Fig. 3. Homecare activities selection for a specific patient.

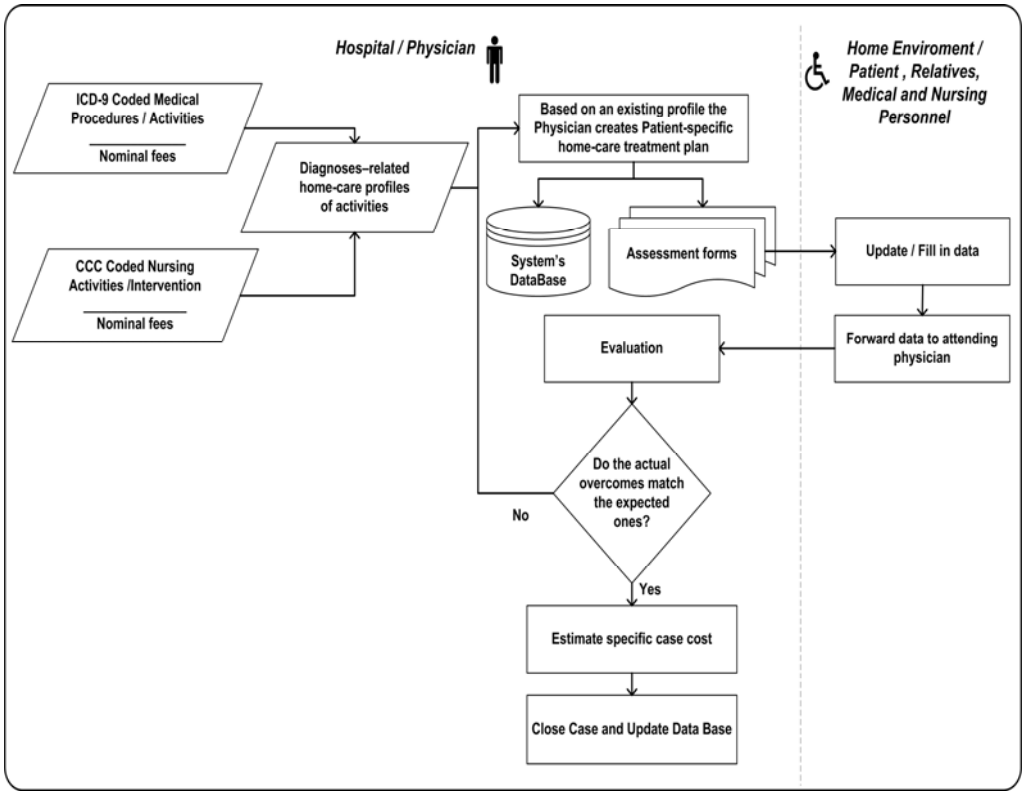

Fig. 4. Details of system's flow chart.

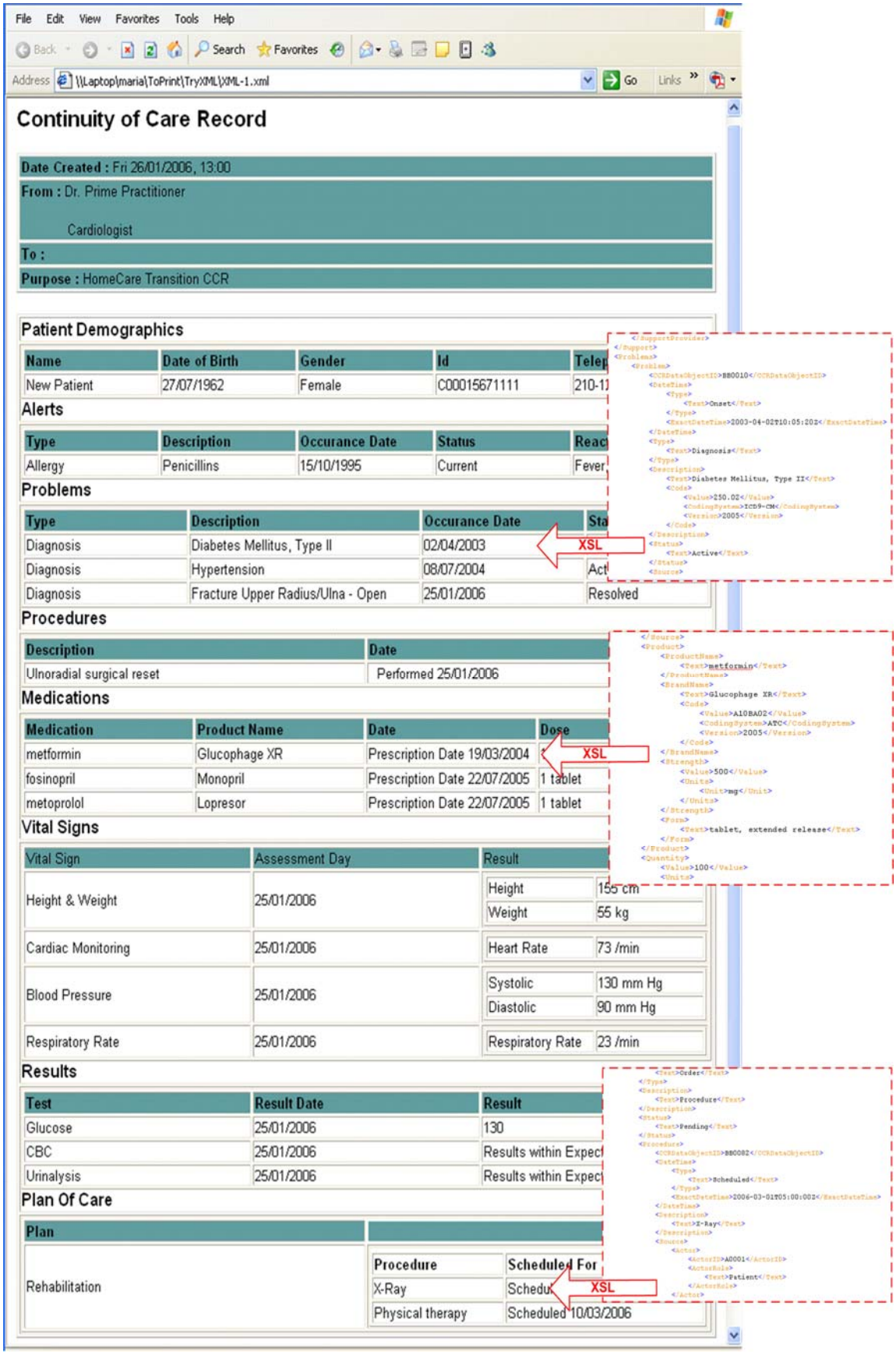

Fig. 5. Details of system's flow chart.

Upon the actual discharge of a patient the physician can use one of the predefined profiles, create a new one or modify an existing one in order to adapt his home-care profiles to specific instances and to emerging new demands. The scheduled procedures are automatically inserted in the CCR in the section of Care Plan. However, the system, apart from producing, electronically or in paper – format, the CCR, also produces a number of additional forms, including advisory and informational notes for the patient himself or for his relatives and diagrams of physiologic measurements, such as glucose, blood pressure etc. that the patient should monitor.

The system also provides for the production of forms that will be filled by the nursing personnel during the care visits in order to document their activities. The filled forms, both the ones regarding the nursing activities and interventions and the ones regarding the monitoring of physiological parameters, are returned to the responsible physician who evaluates them and, depending on his evaluation, can modify the care – plan of the specific patient in any suitable way.

The structure and data of the produced CCR are complying with the ASTM E2369-05 Specification for Continuity of Care Record, while XML is used for the representation of the data. The XML representation is made according to the W3C XML schema proposed by ASTM [6]. The CCR that is produced by the system is currently automatically transformed to HTML format, using the Extensive Stylesheet Language (XSL), in order to be viewable and printable.

It should be mentioned here that the diagnostic and treatment activities are classified according to International Classification of Diseases Version 9 (ICD9), while the Australian Refined DRGs (AR-DRGs) have served for the case codification, and the Nursing Interventions taxonomy of the Clinical Care Classification (CCC) system [7] was used for the documentation of nursing activities.

III. The Semantically Annotated Web Service

Interoperability of health care information systems has become one of the most crucial and challenging aspects in the healthcare domain [8], [9]. Medical data integration is currently a difficult task since the existing health information systems still operate in an isolated mode. Each information system employees currently its own vocabularies and knowledge bases and represents the data in different formats [1], [10].

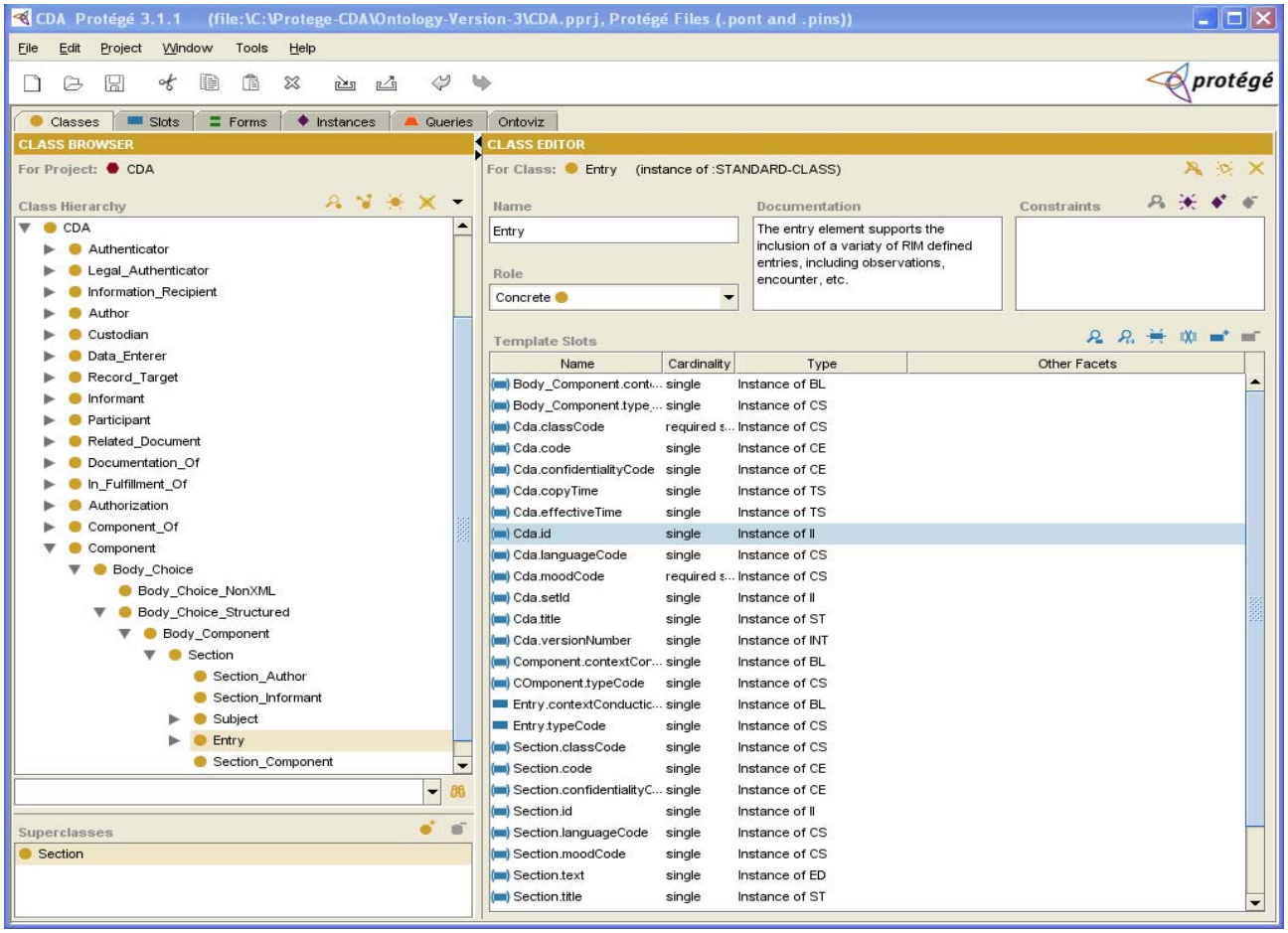

Fig. 6. The CDA class of the ontology

Clinical terminologies and vocabularies, such as SNOMED, ICD-9, ICD-10, and LOINC are already in use for several years and they provide a well established description of the medical domain knowledge. Other healthcare standards,

like the HL7 and the openEHR address the problem of structuring the formats of electronic data exchange among different information systems and of defining the contents of patients' records. These standards provide a certain degree of interoperability and are already in use by numerous healthcare organizations, with the HL7 version 2 being today the most widely implemented medical information standard worldwide [1], [9].

The HL7 Clinical Document Architecture (CDA) [11], [12] in particular is already in use by several countries [13], [14], since it provides for a common representation of clinical documents, enables the clinical document exchange and facilitates document management [15]. HL7-CDA contributes significantly to semantic interoperability, by allowing the structured use of controlled terminologies and promotes the sharing understanding of both the structure and the semantics of clinical documents that are created by diverse information systems. Nevertheless, HL7-CDA cannot by itself be a solution to the interoperability problem since it is unrealistic to expect that all care providers will agree on adopting a single standard and there is currently lack of a globally accepted terminology.

The solution for medical data integration appears to be the employment of computing technologies that are able to comprehend the semantics of the underlying data [1], [8]-[10], [16]. The emerging Semantic Web, which will employee semantically annotated Web Services and in which information will have a well defined machine – interpretable meaning, appears currently to be the most appealing approach towards this direction [16], [17]. At the same time, well established standardization efforts like the clinical vocabularies and the healthcare standards should not be ignored.

The developed system approaches the CDA-documents as domains of knowledge, which describe specific events of a case, such as, for example, a coronary angiography referral. The proper representation of the concepts of these documents, in terms of an ontology, provides for the shared understanding of the document, and allows for the creation of appropriately designed semantic Web Services, exceeding the problems of, both, incompatible formats in messages, and that of the use of diverse vocabularies.

The designed system consists of, first, a prototype ontology based upon the HL7 – CDA, and second, an application that converts the referral documents into a CDA – compliant format and the contents of the CDA – compliant documents into ontology instances. An appropriately designed semantically annotated Web service is responsible for the distribution of the documents over the network, by discovering existing instances of the ontology upon demand.

For the purposes of this paper, Referral ontology was designed, incorporating the HL7 – CDA healthcare standard. The hierarchy of the ontology was defined using the HL7 – RIM entities, the HL7 data types and vocabularies and the HL7-CDA R2 Hierarchical Description. These four concepts constitute the top-classes of the ontology and are further analyzed into a hierarchy of sub-classes, which describe the concepts that belong to these main categories. The vocabularies used were the ICD-9 and LOINC, which were inserted in the ontology as instances of the corresponding vocabularies' classes. However, any clinical vocabulary, such as SNOMED etc., may be employed.

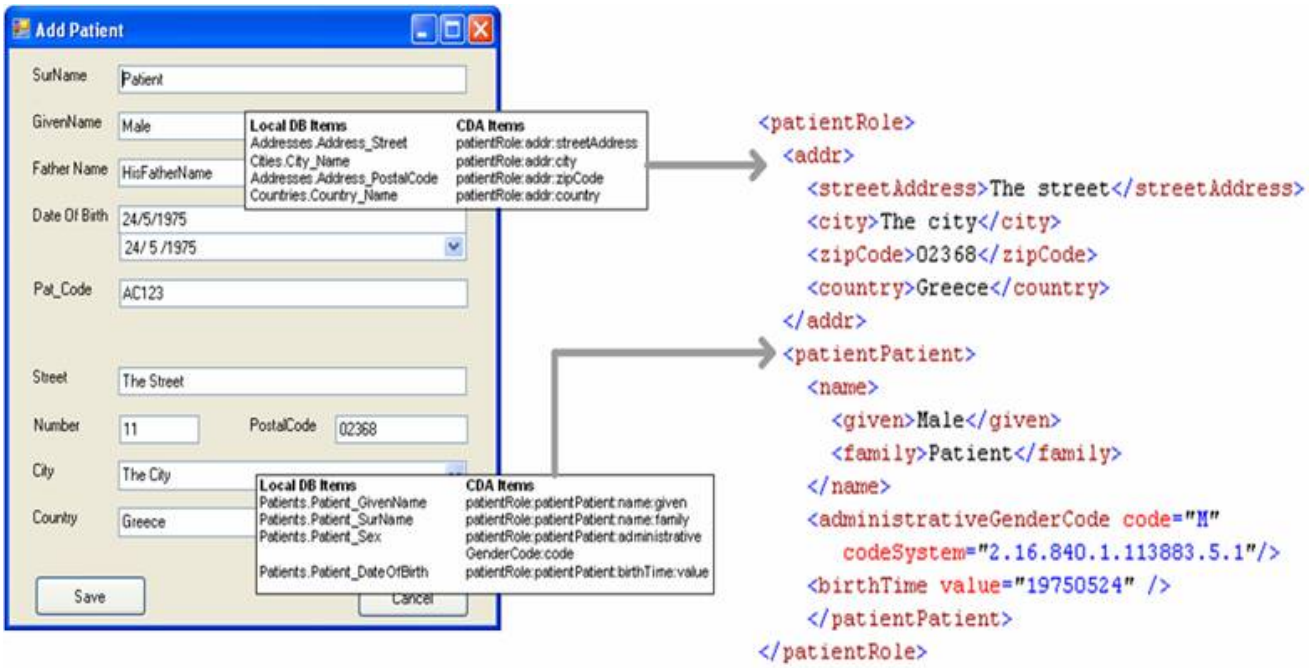

Fig. 7. The CDA – Compliant referral documents.

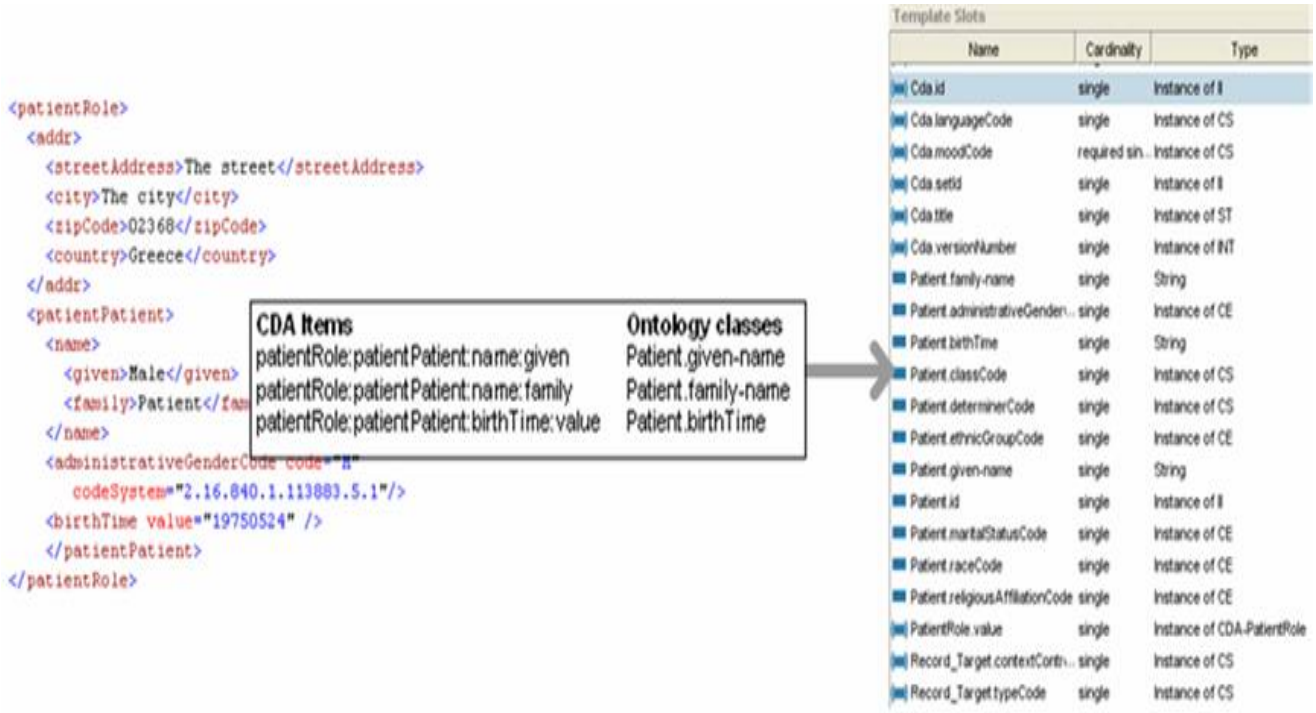

Fig. 8. The addition of ontology instances.

The referral documents, usually containing also static and/or dynamic images are created in a CDA – compliant format. The contents of the CDA – compliant referral documents are converted into ontology instances. An appropriately designed semantically annotated Web service is responsible for the distribution of the documents over the network, by discovering existing instances of the ontology upon demand. The developed service is currently a quite simple one, which enables the discovery of existing instances of the ontology upon the query of the appropriate PatientId.

The service is composed by two processes. The first process accepts as input the PatientId and gives an output that consists of a comprehensive list of the corresponding ontology instances (i.e. the documents that correspond to the specific patient) that were found in the ontology. This list provides for a general definition of the documents (creation date, healthcare provider, etc.). This list serves as the input for the second process whose output is the actual content of the Referral document.

IV. Discussion

The developed system of a Continuity of Care Record combined with a semantically annotated Web Service, is currently being laboratory tested with an EHR system that has been developed by our team. The laboratory implementation indicates that the system, whether interfaced to an EHR or not, is stable enough for practical use and it actually provides a simple, effective and easily expanded tool for the formation of both a CCR and a homecare plan, offering at the same time a good approximation of the individual case cost and a flexible HTML format for data representation, as it is illustrated earlier in Figure 5.

The implementation of the ASTM-CCR Specification Standard confirms that the specific protocol ensures indeed easy document production and manipulation while, at the same time, it assures at least a minimum standard of health information transportability. XML has proven to be the appropriate technology for such an application, since it renders the presentation of information flexible and generic enough to adapt to various users and various software platforms, with minimal custom programming.

Nevertheless, there are some issues concerning the actual use of the CCR that should be taken into consideration, the main one being the fact that, since the physician in charge is actually responsible for the selection of the appropriate / relevant clinical data that should be included in the record, there is always the possibility for the record to become information–polluted by unnecessary data. We believe that the establishment of diagnosis–specific pathways for the formation of special profiles that will support the physicians upon selecting the appropriate data could facilitate the use of CCR and prevent its main characteristic which is its summarized schema.

In the developed semantically annotated Web Service application, the parts of a referral document, usually containing also static and/or dynamic images, can be mapped in a corresponding taxonomy hierarchy, as defined in ICD9 and LOINC. However, any clinical vocabulary, such as SNOMED etc., may be employed. Although the developed service supports currently the discovery of complete documents, the next step will be the selective discovery of specific parts of the summaries, a goal supported by the implemented architecture.

The use of semantic web technologies and ontologies, together with the employment of well established healthcare standards and vocabularies are vital for the promotion of the

interoperability among diverge healthcare information systems. The flexible design concept and the adaptable retrieval mechanism of the proposed system allows for, first, any conceptualization of a continuity of care data exchange procedure, and second, the integration of the structured Referral and Medical Data, in any Electronic or Paper Patient Record System.

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