ENTERPRISE ONTOLOGIES IN HEALTHCARE A PRELIMINARY INCEPTION CONTRIBUTION

David Mendes¹, Irene Rodrigues¹
¹Deparmento de Informática, Universidade de Évora, Évora, Portugal
{dmendes, ipr}@uevora.pt

Keywords: Enterprise Ontology, Health, Semantic Interoperability, Automatic Knowledge Acquisition

Abstract: Current trends in Health Informatics revolve strongly around data interchange issues. Awkwardly, this was a nineties problem in major sectors of the (digital) economy that have evolved steadily to the grander problem of interoperability between systems in most of those sectors. This “semantic” interoperability among information systems is nowadays seen as pretty mature subject in most of the organisations being the commercial sector the leading carrier in this bandwagon. In the late years the efforts towards the formal definitions of Enterprise Ontologies have rendered significant breakthroughs in aligning the “image of the enterprise” (virtual enterprise), that is, its organization reflected in their information systems and the knowledge that can be extracted from them, and the real organisations themselves, their processes and outcomes. This is not yet happening in the Health Sub domain of knowledge and in the HealthCare organisations in particular. Here some contributions are presented to bring both worlds together since there is a strong feeling that the scientific, technologic, political, standardization and personal motivation have just arrived.

1 INTRODUCTION

We will illustrate what steps are necessary to bring the concept of Enterprise Ontology development to the Knowledge domain of Healthcare providing organizations. The problems involved and opportunities discovered are addressed and a proposed Ontological Model, its associated ontologies, tools and techniques to automatically populate/enrich them are suggested.

2 PREVIOUS WORK

We can review the previous work by looking at two basic lines:

1. Enterprise Ontologies
2. Ontologies in Biomedicine and Healthcare

2.1 Enterprise Ontologies

Having steadily evolved during the last years, the concern about the utilization of ontologies as a structural backbone of the knowledge representation about a particular domain as been clarified in what regards to the practical notion of “Enterprise Ontology” in (Dietz and Hoogervorst, 2008) where a standard is proposed (DEMO - Design and Engineering Methodology for Organizations) in order to conceptually define the implementation independent essence of an enterprise, understood from a holistic systemic point of view. The use of this suggested methodology is one of the main tooling for which we argue that we are coming of age in an Enterprise Ontology development in the Health Sector.

2.2 Ontologies in Biomedicine and Healthcare

All the work that has been produced so far in these particular domains of knowledge does not encompass its relation to the enterprise features that have to go side-by-side with the clinical work in a Healthcare organization. The organizational attention to this particular aspect has been, until very recently, been hindered by the slow adoption of IT
knowledge aid tools in the Healthcare providers. If the U.S. reality is considered, one may suggest that only in the American Recovery and Reinvestment Act of President Obama announced in January 2009 considerations are taken to use Health knowledge in a responsible manner to lead into the most efficient use of the funds promised. In Europe the concerns can be traced back to the first half of the last decade since some steps were taken mostly by the research community in aligning the eGovernment initiatives with a rational framework of founded knowledge related IT concerns (Guizarro, L., 2009). Semantic interoperability based in shared ontologies in the Heath area had already strong contributions in Europe due largely to the eHealth initiative that traces back to 2004. A current review that illustrates this area of scientific knowledge is (Cimino, J. J., 2011) and relating to the specific subject of extracting Health Knowledge to automatically populate ontologies a very recent proposal can be found in the authors yet unpublished paper (Mendes, D., Rodrigues, I., 2011) where pragmatic suggestions and solutions are given for the task at hand. A pragmatic approach is presented in order to identify the different issues faced and for each one of them the possible and feasible solutions according to the State-of-the-Art in the Semantic Web and Artificial Intelligence science fields are discussed. Its introduced the proposal of taking advantage of standardization of messaging in EHR (Electronic Health Records) to develop the tooling to finally evolve into "evidence based harmonization" in ontology development meant mainly for clinical practice. The completeness and full coverage of ISO/HL7 (Health Level 7) 27931:2009 Standard will allow solutions that do not fall short in particular fields of the different medical specialities and so they seem suitable for the development of the SAO (Speciality Area Ontologies) mentioned in section 3.2 and introduced is section 4 as part of the proposed Enterprise Ontology. The resulting ontologies have to achieve the sort of user-friendliness, reliability, cost-effectiveness, and breadth of coverage that is necessary to ensure extensive usage as introduced by (Smith, B. & Brochhausen, M., 2010.). Most of the clinical data is in text form coming either from typing entry, transcription from dictation or from speech recognition applications. Ontology population is performed through Information Extraction from the clinical texts embedded in the clinical notes, hence specialized NLP (Natural Language Processing) techniques are to be used. Aligning the extracted information in form of Clinical Concepts introduced in (Cornet R, De Keizer NF, Abu-Hanna A., 2006) and its relationships in Clinical Practice directed ontologies involves classification to some specific ontology (or a network of them) using several NLP techniques. These tasks form a pipeline of NER (Named Entity Recognition), WSD (Word Sense Disambiguation) (Navigli R, Velardi P., 2005) , CRR (Co-Reference Resolution) (Poesio M, Vieira R, Teufel S, 1997) (Soon WM, Ng HT, Lim DCY, 2001) (Ng V, Cardie C., 2001), DR (Discourse Reasoning), EAV (Extraction of Attributes and Values) (Friedman C, Borlawsky T, Shagina L, Xing HR, Lussier YA., 2006), and finally clinical concept matching being these concepts the above mentioned ‘cognitive constructs’. Issues like the GSO (Gold Standard Ontologies) to be used both in the refinement of the clinical corpus but also for ontology enrichment, the adequate sizing of the clinical corpora of documents to use, the clinical semantic similarity of cases and finally the de-identification issues are addressed and discussed in our previous work. The virtues and problems of our proposed approach are discussed but mostly there is a proposed framework capable of achieving the labours of Clinical Ontology producing which entails and shall be further developed here into the Automatic Enterprise Ontology population direction.

3 TWO WORLDS COLIDE: HEALTHCARE ENTERPRISE INFORMATION

The most significant difference between the Healthcare providers and any other common enterprise lies in the Human factor itself due to the strong scientific individualism that MDs and other health workers demonstrate. In most of the economical sectors the average provider organization follows sector normalization, templates and standards, and abiding to those regulatory artefacts rends meaningful interoperability tractable since there exist semantic shared concepts that are “universally understandable” and consequently interchangeable according to the ground terminologies and ontologies. Clinical practice, however, is done with many personal practicalities and that is easily figured from the form how the activities are documented, mostly in free form text notes like diagnostics, clinical findings, patient histories, allergies, discharge or transfer notes to name a few. It is obvious by the frequency that speech recognition devices and specialized software
is used, or notes typed manually into text entered in the EHR systems that this is the main form of knowledge recording in this specific domain. Rigid protocols no matter of how completely scientifically proven or hierarchically enforced within the organization tend to become a failure if they don’t allow for the personal idiosyncrasy of the particular practitioners. The way the information is then encoded and subsequently retrieved, automatically or manually, to create, enrich and verify a given ontology is through text recognition and suitable (Enterprise) ontology alignment. For automation purposes, only applying the recent AI developments in the Ontology Engineering research area like Automatic Ontology Enrichment in the Semantic Web to a sound and proven Enterprise Ontology developed according to the DEMO standard introduced above will lead into a complete, consistent and coherent set of ontological aspect models.

3.1 Paradigm shift in Enterprise Architecture of Healthcare services

In order to increase the quality and safety of services delivered to the patient and to increase efficiency and efficacy of the care delivery process the systems are turning from organization centered into person centered care. The recent arrival of the personalized offerings transcend the borders of any health care providing system as well as those of localized institutions. This phenomenon, embodied by the corporate IT huge investments as the Google Health (https://health.google.com/health) initiative to be discontinued in January 2012 or Microsoft Health Vault (http://www.microsoft.com/en-us/healthvault) renders the significance of different Health IT systems less relevant by being isolated no matter how important they might seem to be. That is, even the most widely implemented EHR or PHR systems lack importance if not able to connect vertically with pervasive devices for health data acquisition and monitoring as with services generally available in the Internet at large as horizontally across medical specialities and across geographical boundaries. The enforcement of the care continuum is no longer determined by the definition of care processes, management roles and architecture in the organization itself for they are no longer carried within the Enterprise as a single organization (Hospital, Primary Care, Ministry of Health, ...) independently of its dimension but has to take into account their involvement in their regional environment, the different levels of care that relate to each other as Emergency, Primary, Secondary, Tertiary, Quaternary (Investigation), Continued Care (CCR), PHR where they all have to “understand” each other and the Enterprise Architecture here is not applicable to a particular organization but the notion as to be widened to the new paradigm of personal care. Population-based medicine (Leva, A.D., Occhetti, D. & Reyneri, C., 2004), is a structured response to a set of problems of healthcare systems which results in:

- reduction of costs in the health care environment by means of the improvement of performances (diagnosis and therapy pathways, hospitalisation, etc.);
- redirecting of services and capabilities towards the consideration and care of the overall needs of the patient-person and not only focusing on the purely medical needs of the clinical-case;
- creating a network of care structures, aimed to compare schemes and experiences in medical practice, for continuous information exchange and improvement;
- increasing patient satisfaction by providing, in less time, the best practice and more complete assistance to take care for the whole needs related to a patient’s disease;
- enhanced synergy under the organisational, cultural, informative and formative point of view, enhancing the quality of care processes and, most of all, the quality of a patient’s life.

This new paradigm is driving the new extended enterprises to adopt a new knowledge structure and thus the need and acceptance of scientific proposals like this one.

3.2 Considerations for the Enterprise Ontology to be developed

For the new Enterprise Ontology to have a high degree of coverage it has to encompass 2 of the important activities closely related in the Healthcare organizations that are the (1) care providing and (2) the general management activities that are in use in
the organization and can be usually subject of easy (re)designing and (re)engineering due to the fact that they are usually tuned up for the previous paradigm of the “isolated”, “pre-knowledge-cooperative” enterprises. A particular amount of attention has to be taken into the levels of “knowledge interaction” between the 2 major sub-domains referred. This issue will be addressed further in Section 4 and is of particular interest because it conforms a “kick-back” effect that different parts of our enterprise generate in their specific lower level ontologies, namely the Speciality Area Ontologies (SAO - to be introduced later) in the Management Area Ontologies (MAO - introduced later as well) and vice-versa and in the multiple levels of the extended enterprise and its corresponding ontological model.

One of the major problems is represented by the difficulty of establishing a partnership among different enterprises and making them sharing, in a short time, a common understanding of this given application domains. The construction of a common ontology is a promising solution to this problem. The cornerstone that is inevitable to handle here is to deal with it using the “white box thinking” as introduced in (Dietz and Hoogervorst, 2008) about the shared semantics Enterprise Ontology instead of the former “black box thinking” that was previously suitable. In our proposal we take into account a separation of concerns to deal with the paramount task of defining an enterprise ontology by dividing it in separate levels trying not to render it neither to specific nor to comprehensive as suggested in (Bertolazzi, P. et al., 2008) and we fragment in different levels including a CEO (Core Enterprise Ontology) and refining into 2 lower levels namely HCO (Health Care Ontology) and SAO (Speciality Area Ontologies) as introduced in (Leva, A.D., Occhetti, D. & Reyneri, C., 2004) but now in a more comprehensive reach trying to represent all the Enterprise with a related ontology. The intermediary level HCO will function as aggregating path for the SAO (e.g. A physiotherapist asks for a MRI and the flow of information traverses the SAOs but stays coordinated according to the HCO enforced ruling) and the sidewalk MAO (Management Area Ontologies) (e.g. the service billing and staff allocation has to be guaranteed also according to the upper level controlling ontology in the HCO).

4 FROM THE ONTOLOGICAL MODEL TO THE ENTERPRISE ONTOLOGY

The last years have offered the Health workers a due share of satisfaction parallel to the fears and amount of duties involved in the above mentioned paradigm shift. The understanding of the construction and operation in a fully implementation independent way of the new systems, that is its ontological model, is being observed by the participants as an amazing opportunity of aligning the IT knowledge centered systems with the actual (re)engineered enterprise but simultaneously plagued with a fair amount of disbelief about the availability of the current scientific and technical abilities of the 3 communities involved (IT, Medical and Health Management) in developing and accepting/incorporating the major concepts and tooling involved. We want to render intellectually manageable the substantial strategic changes of enterprises. By using the theoretical constructs in (Dietz, J. L. G., Hoogervorst, J. A. P., & Nederland, S., 2008) we propose the ontological modeling of the enterprise that covers static (structure), kinematic (process), and dynamic (action) issues in such a way that the resulting models can be executed or simulated. In the HealthCare domain one may consider the P-acts and the clinical practice activities documented in any kind of form and the C-acts the (or at least a significant part of them) are the management activities in the enterprise. The real interesting challenge in our proposed methodology is that the knowledge extraction about all P-acts builds the image of the organization activity and serves as the foundation for the C-acts to be performed. But as devised in the Enterprise Ontologies model here considered these later performed acts shall be inserted back into the Enterprise Ontology structure. Hence the “lower level” ontologies have to consider the segmentation of the clinical activities in SAO according to the
natural differentiation in clinical services in a given organization like, for instance, Cardiology, Oncology, Paediatrics, but also consider the “transversal services” as subject of SAO like Radiology and Nuclear Imaging, Laboratories such as: Clinical Analysis or Blood Bank, Pharmacy or Social Services to name a few. These ontologies are to be enriched through the use of the methods introduced in section 2.2 and are forged mainly from the analysis and knowledge extraction from “traditional chart components” such as:

- Progress Notes
- Orders
- Procedure Reports
- Discharge Summaries
- Problem Lists
- Lab Results
- Vital Signs

And other chart components” as:

- Annotated Diagrams - Stick Figures
- Advanced Directives
- Consent Forms
- Flow sheets
- Admission and Referral Forms
- Reports from other medical facilities

Augmented with chart components like:

- Automated alerts for allergies, directives
- Periodic Clinical Reminders
- Inpatient Status and Location
- Outpatient Appointments

and more.

MAO, however, should use the common ontological structures thoroughly discussed and developed in the ERP (Enterprise Resource Planning) Communities since they are truly a step ahead in what relates to IT latest trends availability than “pure” Health IT.

5 CONCLUSION

A humble contribution is provided in this work in pointing directions in using current available scientific knowledge, tools and trends in its applicability to Health IT, and namely to Enterprise Ontology in this particular domain of scientific knowledge and activity. It is argued, based in the current state of the art about standards, tools and technologies in the Semantic Web area of AI research that the time of developing Enterprise Ontologies that represent the model of the new “personal health” model of care organizations has arrived. These are, however, the beginning of times in this amazing breakthrough era of Knowledge oriented organizations and the tools that the new Web is bringing along for them, but the promised enhanced capabilities in care providing are huge and socially its effects will be no less than astonishing.

REFERENCES


Bertolazzi, P. et al., 2008. An Approach to the Definition of a Core Enterprise Ontology : CEO Meta-Level Intensional level ( Conceptual model ) Extensional level ( Model ) Interchange


