Clinical Decision Support Using Open Data

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Abstract. The growth of Electronical Health Records (EHR) in healthcare has been gradual. However, a simple EHR system has become inefficient in supporting health professionals on decision making. In this sense, the need to acquire knowledge from storing data using open models and techniques has emerged, for the sake of improving the quality of service provided and to support the decision-making process. The usage of open models promotes interoperability between systems, communicating more efficiently. In this sense, the OpenEHR open data approach is applied, modelling data in two levels to distinguish knowledge from information. The application of clinical terminologies was fundamental in this study, in order to control data semantics based on coded clinical terms. This article culminated from the conceptualization of the knowledge acquisition process to represent Clinical Decision Support, using open data models.

Keywords: Clinical Decision Support · Clinical knowledge · OpenEHR · Terminology

1 Introduction

Upon a patient going to a healthcare unity, a data set about his health is stored in an Electronic Health Record (EHR) system. Such practice aims primarily to eliminate the use of paper and has been increasing on a large scale currently.

Commonly, a health facility integrates several heterogeneous systems that, somehow, speak different languages [1]. These systems must be interoperable, i.e., be able to communicate in a noticeable and effective manner. This focus is based on building communication without data loss and on the meaning of its content, specifically referred to as semantic interoperability.

Thereby, the OpenEHR approach and the clinical terminologies aim to achieve universal interoperability between EHR systems [2]. The first, structure archetypes to represent clinical concepts, and the second is based on the use of structured vocabularies correlative to clinical terms. Thus, data exchange between systems does not compromise the quality of receptive information.

Nevertheless, a simple EHR system became incapable to support decision making in daily basis, because its primary role was merely to store and consult clinical records [3]. Hence, this inefficiency propelled the need to explore new techniques for gaining

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clinical knowledge and semantic interoperability in order to improve decision process in healthcare.

In this sense, this case study was aimed to explore the OpenEHR and clinical terminologies, in order to improve semantic interoperability between systems and to formalize the Clinical Decision Support practices, providing open clinical knowledge.

This paper is divided in five sections. The first one introduces the groundwork of the present case study. The second describes key concepts in the applied field such as open data, OpenEHR, clinical terminologies and clinical decision support. The third section presents the methodology applied to develop this case study. Following the Knowledge Acquisition method, the project development is exposed in the fourth section. At last, in section five, conclusions are drawn from the work done and it describes the future work.

2 Background

2.1 Open Data

The Open Knowledge International's Foundation [4], the most important international pattern to open data, granted the first definition to open data as "data that can be used in a freeway, shared and built for anyone, anywhere and to everything". Consequently, open knowledge is defined as "any content, information or data that society is free to use, reuse and redistribute, without any legal, social or technological restriction".

To summarize, the term "open data" has gained popularity in the transparency and open government movement around the world, as it manages the access to public information as a rule and can be freely used, modified and shared by anyone and without any financial or other restrictions and it is also applied to the health domain [5].

2.2 OpenEHR

The OpenEHR approach follows the open data and free access standard for health information specifications and is used in management, storage and querying of electronically clinical data. The use of this model provides an interoperable framework that organizes clinical content with patient information, thus enabling integration with different health information systems [6].

The OpenEHR Foundation states that OpenEHR has "multilevel single-source modelling within a service-oriented software architecture where models built by domain experts are in their own layer". In this sense, the OpenEHR architecture consists of two levels, which information and knowledge are separated.

In the first level, the information model groups and defines the information processed in the system for each patient, followed by information components such as quantity, text or date concepts. The second model holds the clinical knowledge applied in a structured and archetype-oriented manner, according to the Archetype Definition Language (ADL), promoting semantic interoperability [7].

2.3 Clinical Terminologies

The mutual understanding of the vocabulary used in services or data between all the actors in a system, is represented by the semantic interoperability [8]. To facilitate and solve semantic problems in healthcare systems, the concept of clinical terminology is applied.

The use of clinical terminologies aims to promote semantic interoperability in EHR systems, which clinical terms are coded and represented according to a given standard [9]. Therefore, these terminologies are referred as the meaning or expression of clinical concepts where it is composed of terminological reasoning based on the classification, relationships and comparison of individual concepts imposed on the system [10].

Nowadays, there are many examples of health terminology and classification systems. However, this case study will use only the International Classification of Diseases version 10 (ICD 10) and the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT), although they will not be delved further.

ICD uses a common language in several classification countries that usually refers to the patient's overall situation and can expose symptoms, illness, injury and even death [11]. This is based on translating sentences for diagnosing diseases or other health problems into alphanumeric codes for all universal epidemiological purposes.

On the other hand, SNOMED CT is a health focused terminology that has a medical nomenclature for numerical coding of clinical terms. The core part of SNOMED's operation is conceived through a hierarchical structure of three components: concepts, descriptions and relationships [12].

2.4 Clinical Decision Support

Friedman [13] presented a theorem that states that an individual or group working with a technological resource performs better than one who works without assistance. For the validation of this theorem the information system must be valid and reliable, and the user must know how to use it properly.

The activity to support decision makers in healthcare is designated as Clinical Decision Support (CDS). A CDS is an activity or a service that involves a range of mechanisms that represent clinical knowledge in a structured way that aims to support all involved in healthcare domain [14].

Nevertheless, the need to provide such practice in a computable application or tool, is represented by a Clinical Decision Support System (CDSS), combining engines and predefined rules to provide CDS. Over an efficient and reliable information system infrastructure to enhance CDS practices, the CDSS gives patient related information to the user in any decision-making moment in healthcare.

Most EHR systems are encouraged to or already include CDS practices to build a CDSS. For such purpose, knowledge acquisition techniques are required to deploy and organize rules in a knowledge base, in order to support decision making [15].

3 Knowledge Acquisition

To complement this study, the Knowledge Acquisition methodology was applied in order to develop a Clinical Decision Support framework. This process is characterized by the extraction, structuring and organization of replicated human knowledge adapted to a machine-readable format [17]. This model has several phases, but this project is restricted to four steps.

3.1 Identification

The need to acquire knowledge through daily production of electronical health records (EHR) has spread. However, it is essential to distinguish three concepts for a better understanding of what is approached as clinical knowledge.

According to Zins [18], data are unstructured facts resulting in a qualified or quantified interpretation without context. Information is the contextualized and structured data, following a purpose. In this sense, knowledge is the information acquired with theoretical and practical understanding based on experience, involving informed individuals, practices and organizational norms in a given domain.

As the knowledge encompasses several areas of learning, the clinical scope is also covered. Therefore, the clinical knowledge is defined by Winters-Miner et al. [19] as the "cognitive understanding of a set of known clinical rules and principles based on the medical literature, that guide decision-making processes".

3.2 Conceptualization

In order to complement EHR systems in decision support, the clinical knowledge acquisition through clinical guidelines and practices are crucial for the validation of this new process. For such purpose, it is necessary to define the essential components to acquire the desired clinical knowledge.

Thereupon, the new process is based on the implementation of the OpenEHR approach and clinical terminologies for the construction of the new open knowledge model. Following the essence of the OpenEHR approach, clinical records inserted in a determined system are modelled on two levels [20].

OpenEHR architecture models data in two levels, sorting out information and knowledge (Fig. 1). In this sense, information is defined as quantified and qualified patient-oriented data, as well as their respective demographic data, grouped in the OpenEHR reference model.

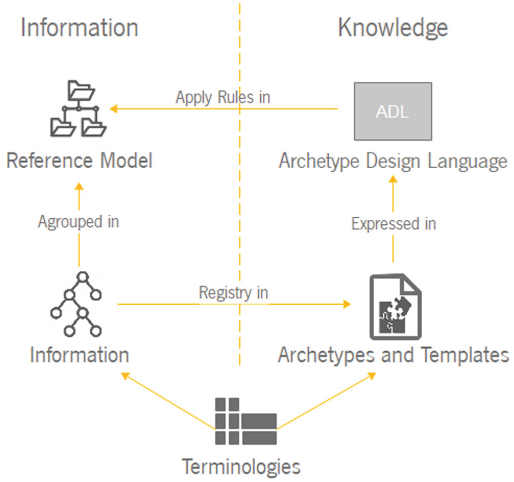

Fig. 1. OpenEHR architecture

On the other hand, knowledge aggregates the clinical content based on medical guidelines that are represented by archetypes, in order to form templates that document such knowledge. For proper implementation, archetypes and templates must follow a set of rules encoded in Archetype Definition Language (ADL).

The ADL defines the structure of the document that embodies medical knowledge, represented by the templates. In order to code clinical terms, the terminologies are also implemented on the structured template and it is applied directly on template modelling.

To summarize, this mechanism separates these two concepts to allow the manipulation of data in an organized manner, relating them by the need to fill the template components with patient information.

3.3 Formalization

The two-level modelling approach defines an archetype-based architecture which provides the desired information of a given patient, combining clinical knowledge without losing the clinical meaning of the content and preserving the confidentiality of each data as intended by the patient [21].

OpenEHR methodology focuses on interoperability between systems, with the adoption of open specifications and clinical content. Thus, the main purpose of such adoption is to transform clinical records into a structured and interpretable model.

The formalization of this new process (Fig. 2) is initiated by the representation of the health professionals who represents all entities involved in a health facility that have authority to record both administrative and patient data in an EHR system.

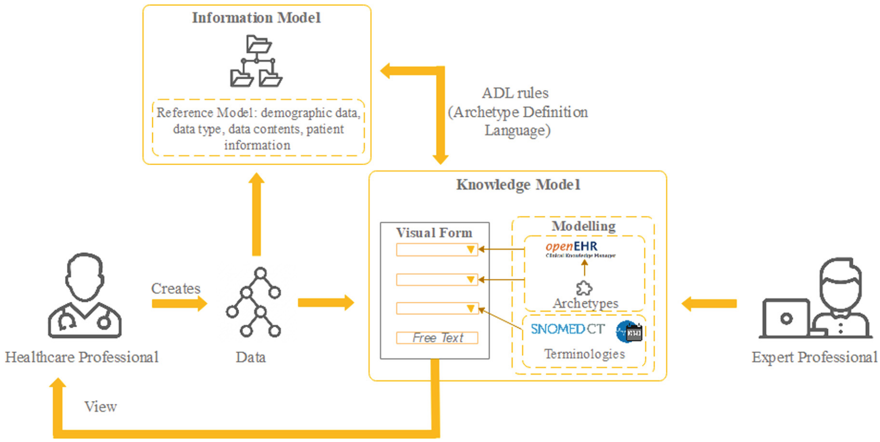

Fig. 2. Knowledge modelling

OpenEHR methods allow forking data in two directions. Information model is understood as the data semantics in a structured form, constituting the OpenEHR reference model. In opposite, the knowledge model focuses on clinical content, represented by archetypes and templates through a set of rules.

The knowledge model is then developed by an expert professional from a certain domain. It selects and aggregates a set of archetypes according to the intended clinical purpose for building a template through the appropriate platform OpenEHR Clinical Knowledge Manager.

Clinical terminologies and classification systems are implemented and controlled in template modelling. The use of coded clinical terms is required for the representation of appropriate diagnoses or symptoms of a given patient, providing semantic interoperability in template components. In addition, ADL rules are required for proper functioning and modelling consistency for future information management and storage.

After the modelling process is completed, the resulting templates are transformed into a structured view format, labelled as form. This form displays, to the health professional, the representation of clinical knowledge along with previously registered patient information. With this implementation, the reverse process of logging data via a form is also applied.

3.4 Knowledge Representation

The formalization of clinical knowledge and information was applied and articulated in parallel to a set of rules. The large amount of data resulting from that distinction has generated a substantial need to exploit a new storage technology resource.

Thereupon, the need for a new clinical data repository (CDR) system and the representation of clinical decision support (CDS) activity were crucial aspects to be engaged to increase quality in health care.

Thus, CDR is defined as a distributed real-time database that allows data storage originally entered from other clinical data sources [22]. Their function is querying data in an easy and arbitrary way to a possible analysis of reports and results.

In order to represent clinical decision support practices, an architecture was proposed that represents such activity using open clinical knowledge techniques (Fig. 3). It is crucial to emphasize the need to distinguish activity and technology. Thus, the CDR was also highlighted and was developed in parallel with another case study.

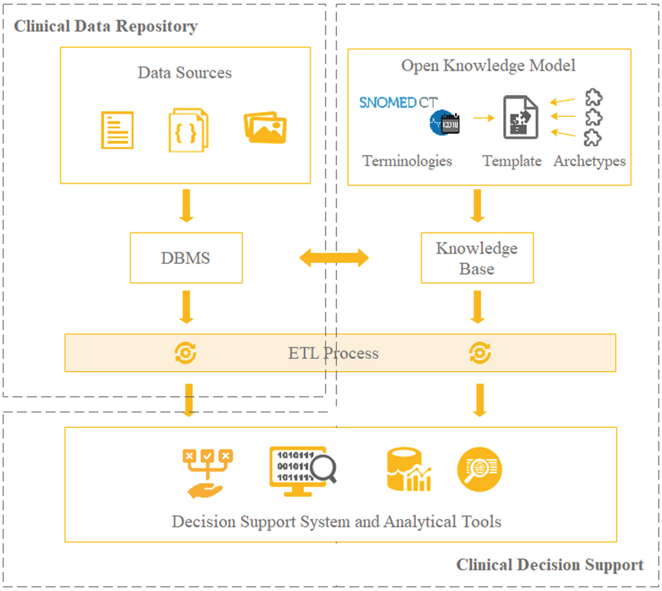

Fig. 3. Clinical Decision Support framework

After data registration and collection on a specific system, it is stored in heterogeneous data sources and represented in a database management system (DBMS). In parallel, the modelling practice of OpenEHR and clinical terminologies is characterized by the open knowledge model, resulting in the creation of a knowledge base.

CDS practices focus mostly on the knowledge base of the system fuelled by clinical knowledge. The open knowledge model loads its knowledge to this base as a processable and interoperable format by machines. As a result, migration rules are applied between DBMS and Knowledge Base in order to associate patient information with clinical knowledge in a structured form.

In this way, the CDS module has key elements that characterize it, such as the organized representation of knowledge, the structured and controlled vocabulary for clinical concepts and the knowledge base. Extract, Transform and Load (ETL) process are also applied which allows querying and cleaning data for future interaction with decision support components.

The final layer of decision support activity integrates the computer system that will represent such acquired knowledge. A CDSS is a technology or tool that integrates patient knowledge and clinical information in a structured way to support decisions and actions in health care delivery. For that purpose, other analytical tools are also applied, representing data analysis.

4 Conclusions and Future Work

This case study aimed to explore components that provide clinical knowledge in order to build a Clinical Decision Support (CDS) module to improve EHR systems and quality in healthcare. Thus, this case study integrates knowledge acquisition methods such as OpenEHR and clinical terminologies, providing a two-level modelling.

As a result of separating clinical records into information and knowledge, a set of archetypes and a common controlled vocabulary are modelled to represent clinical concepts and terms in a structured form. This set of activities characterizes the open knowledge model, that aggregates templates and visual forms following a clinical purpose.

Thereby, a set of rules to the decision support activity were applied, capable of ensuring the consistency and coherence of the information that was risen by the use of such techniques, granting clinical knowledge in an organized and standardize way.

Overall, the clinical decision support activity is characterized by a knowledge base through the open knowledge model. As a result, these interactions allow the system to be faster, interoperable, organized and easier to use. In addition, the new process applied allows professional with no clinical expertise to be able to intervene and contribute to the conceptualization and structuring of health information systems.

To sum up, the CDS activity complements a simple EHR system, providing clinical guidelines and documented models, to find suitable standards for representing clinical data in order to achieve decision support benefits in healthcare.

Future work is sustained by two approaches. Firstly, the use of open knowledge models will be continued in order to framework all the necessary templates for structured visualization of clinical information through forms. In the second instance, the Clinical Data Repository will be explored and implemented, in real time, incorporating information and knowledge models.

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