THE OPENEHR ELECTRONIC MEDICAL RECORD IN CONTENT MANAGEMENT SYSTEMS: TOWARDS AN IMPLEMENTATION

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Christiano Pereira Pessanha[1].

ABSTRACT

This article describes research motivated by the challenges arising from efforts that seek semantic interoperability in Electronic Health Records (EHR) via the OpenEHR standard. The research sought the implementation of OpenEHR information models in Python language, as these models provide the semantics necessary for the construction of OpenEHR archetypes. As a contribution, it implements and opens the perspective of expression of the OpenEHR Archetypes on this platform, suggesting the feasibility of implementing this pattern in the various language frameworks. The research analyzes the requirements involved in the implementation of the OpenEHR standard in RES software coded from scratch, verifying the various advantages of its implementation in CMS's. The result of this theoretical effort clarifies the possibilities of building this type of software in content management systems, in general.

Keywords: Electronic Health Record. Interoperability. OpenEHR archetypes. Content Management System.

[1] Dr. in Information Science
Fluminense Federal University (UFF) – Department of Information Science (GCI)
Email: chpessanha@id.uff.br
Orcid: https://orcid.org/0000-0002-0256-3179

INTRODUCTION

The electronic patient record (EHR) was developed for doctors and nurses to recover clinical facts in a systematic way, allowing everyone access to the same information, speeding up treatment and reducing errors. Filing in individual files leads to problems (Massad, 2003) such as illegibility, ambiguity, misreading, absence and loss of information, among others. Thus, the Electronic Health Record (EHR) has been proposed as a means to organize and streamline the registration and access to clinical information.

However, increasingly, patient records are distributed in databases of different information systems of hospitals and clinics. From this challenge came the worldwide effort to make interoperability between these systems a reality. Health institutions aim to be able to exchange data, making information available between professionals and for the patient himself. OpenEHR[2] aims to enable interoperability between RES systems (Beale; Heard, 2008), representing clinical knowledge via metadata standards called "archetypes". External to the system's codes, medical experts can manage them independently by representing complex concepts, such as "blood pressure" or "family history". A motivating factor for the adoption of archetypes is the prospect of reusing clinical knowledge, well specified and validated by reference organizations (Nardon et al., 2008).

For the construction of reusable archetypes, the standard specifies a reference model, stable and generic core that defines the generic blocks to build archetypes (Beale, 2002). Thus, any implementation effort on a programming platform must first answer the question: is it possible to express clinical information according to the OpenEHR standard on this platform? It is in line with this effort that this research proposed to collaborate, at first, by verifying the possibility of expressing clinical information in the OpenEHR standard, in the Python programming language.

Secondly, once this possibility has been verified, the gains brought to clinical information management by its implementation in content management systems (CMS) are analyzed.

It is in the context specified above that this research presents contributions to the generic problem of health information management.

ARTICLE STRUCTURE

The order of presentation and themes of each section were defined as follows: Section 2 describes the factors that motivated the development of the research; Section 3 deals with the *design science research methodology*; Section 4 exposes the aspects

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[2] TIOBE Index, institutional page:< http://www.tiobe.com/index.php/content/paperinfo/tpci/index.html>

related to semantic interoperability in EHR and the use of reference models as a solution to this challenge; Section 5 presents the dual model and ontologies, bases for the OpenEHR standard; Section 6 exposes the OpenEHR standard, details of the formulation of the CIR ontology, which serves as the basis for its reference model and its model of knowledge or archetypes; in Section 7, results of the effort to implement the OpenEHR reference model in python as well as the analysis concerning the implementation of RES in CMS's. Finally, Section 8 presents the conclusions of the research.

MOTIVATION

One of the great motivators for the adoption of archetypes in the construction of applications is the prospect of reusing well-specified clinical knowledge validated by reference organizations. It is, therefore, essential for EHR programs, which seek interoperability, to adapt to standards aimed at this purpose, such as OpenEHR.

According to Kobayashi and Tatsukawa (2012), the current implementations of the OpenEHR standard, considering the adoption statistics of the languages used, provide resources for approximately 25% of *software* developers, so additional implementations are necessary to broaden the user base.

Thus, a positive result regarding the problem of the expression of archetypes in the Python platform enables the development of applications aimed at the management of clinical information in this platform[3]. In turn, this result allows an analysis to be carried out that makes it possible for the proponents of such systems to decide between an implementation whose coding starts from scratch and the use of a CMS.

Therefore, the main objective of this research was to verify whether the models (reference and archetypes) of the OpenEHR standard can be expressed in the Python development platform, as well as the possibility of using a framework such as content management systems or CMS's for the implementation of PEP/RES-type systems, according to the OpenEHR standard.

METHODOLOGY

The need to deal with issues of a practical and theoretical nature, nested and interdependent, led to the adoption of *design science research*[4] as a guiding paradigm for the methodological trajectory of this research. The approach allows, in the specific case of

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[3] We chose to use the original term "*design* science *research*", since the translated term has not been adopted, at the time of writing this work, in the academic literature researched.
[4] The Python code resulting from the implementation effort for each information model can be accessed in the online repository: <https://github.com/chrispess/Doutorado_ECI/tree/master/openehr>.

information systems, to work with the creation of new knowledge through the design of algorithms, interfaces, methodologies, among other practical results.

Thus, the possibility of working with knowledge characterized as formal, as well as material or empirical, is pointed out. In fact, this research, in its first part, seeks to enable the expression of archetypes via OpenEHR semantics in Python, that is, an empirical effort. Next, it suggests the analysis of the possibility of implementing OpenEHR RES in CMS's, in a theoretical effort of analysis.

As an essential characteristic, *design research* emphasizes the connection between two types of problems, practice and knowledge, seeking to show that scientific knowledge can be produced through the *design* of useful artifacts (WIERINGA, 2009).

Thus, the context of this research, permeated by problems of different natures, nested and influencing their solutions in a chained way, is consistent with the *design research methodology*.

SEMANTIC INTEROPERABILITY IN RES

The recording of clinical information via local EPs limited its use. The significant variation between the systems used increased the informational complexity and made it impossible to compare data from different hospitals and clinics.

The heterogeneity of information is a direct consequence of the large number of existing data models and forms of representation, structure and syntaxes of different data between information systems. At this level, the semantic aspect is also considered, that is, the various interpretations that these data can receive in different contexts of information systems. These differences make the integration of different information systems used by health institutions a complex process. Integration is the arrangement of an organization's information systems into a single system. Interoperability, on the other hand, is the ability of information systems to work together, internally and externally across organizational boundaries, in order to promote effective service delivery (HIMSS, 2010). Thus, interoperability implies different information systems aggregating their forces in favor of a common goal, without, however, altering their autonomy and their own characteristics (Sheth, 1999). At the semantic level, the meaning of the information that is exchanged must be guaranteed by the sharing of a common vocabulary.

The scenario in which EHR systems are found is characterized by heterogeneity, among other factors, as a result of an informational complexity arising from the various medical specialties, terminologies, cultures and languages. There are also the various medical record systems available on the market, with specific functionalities for different types of organizations. These factors help to explain the importance given to achieving semantic interoperability for EHR systems. According to Kalra (2007), the international community considers the achievement of semantic interoperability between EHR systems essential when thinking about the future of health services, where the use of terminologies, ontologies and archetypes compose the core of such a challenge.

As Nardon (2002) points out, of the various challenges and cultural changes necessary for the development of these systems, from a technical point of view, the challenge of interoperability and the complexity of information make their development more difficult than the development of other information systems.

INFORMATION MODELS OR REFERENCE MODELS

The use of generic information models or reference models has been an internationally accepted approach to achieve semantic interoperability between EHR systems. In general terms, they define a standard for representing clinical data and its common properties. When the same generic information model is used by EHR systems that need to interoperate. Clinical data must be shared in the correct format, even if the nature of the clinical content has not been previously agreed upon (KALRA, 2007). In addition to the generic information model, there are clinical data structures and clinical terminologies. Clinical data structures allow the classes of the information model to be used to consistently represent the relevant clinical concepts (KALRA, 2007). In turn, terminologies are used in the codification of knowledge in the EHR, aiming at a correct interpretation of the data involved, both for humans and machines (HL7, 2010). The development of standards or reference models came, therefore, as an answer to the type of problem presented when seeking interoperable and cost-effective EHR systems.

KNOWLEDGE REPRESENTATION AND ONTOLOGIES

DUAL MODEL

By trying to implement, through the traditional approach of development at a single level, systems that present the degree of complexity and demand that EHR systems need, a system of difficult maintenance, short useful life and high cost was obtained (Beale, 2007). The two-level approach, arising from the knowledge representation techniques of A.I., proved to be adequate to avoid these consequences, with one level referring to the domain model and terminologies and the other to the information model, seeking to leave the generation of knowledge directly under the responsibility of specialists with little (ideally none) dependence on information technology professionals.

THE DUAL MODEL

The development of systems of this nature requires that knowledge about the domain be specified in an abstract way, obtaining the desired specification, and then codifying it. By following this procedure to generate a system, focusing on specifying knowledge unlinked to a specific code, external to the system, the researchers saw advantages such as **ontological or knowledge engagement** (meaning that the logical sentences that describe the specification have a more direct relationship with the modeled domain), readability, inference capacity, semantic fidelity, reusability, knowledge portability, independent of the implementation code and therefore independent of the machine. These characteristics are attractive for efforts to develop dual **model systems**, separating domain knowledge from the rest of the system.

ONTOLOGY

Once knowledge related to the domain is obtained, detached from the specifics of implementation, the so-called ontological level of the types of primitives used in the description of a knowledge system becomes important. Guarino (1995) proposed, for such systems, the insertion of an Ontological level, where the meaning associated with a language of knowledge representation could be formally restricted.

Ontologies can be seen as a contemporary response to a need for knowledge-based systems. One purpose is to favor the sharing and reuse of knowledge stored in systems created for the most diverse purposes. The latter, before the predominance of the Internet, could not be shared or reused. In general, it was organized in knowledge bases isolated from each other, in different languages, without interfaces capable of integrating them and, therefore, without interoperability.

One of the most important definitions of ontology comes from the Computer Science line of thought. According to Gruber (1995, p.1): "an ontology is an explicit specification of a conceptualization". Therefore, for this author, all formally represented knowledge is based on a conceptualization: objects, concepts and their supposed relationships. This conceptualization is a **simplified and abstract view of the world** one wishes to represent.

Guarino (1995, p.2) presents his definition of ontology as: "a logical theory that explicitly and partially explains a conceptualization". From this definition, it can be seen that an ontology provides an understanding of a shared conceptualization of a given domain, a common vocabulary free of ambiguities. Ideally, any instance that makes use of a domain's data and metadata should adhere to the corresponding ontology.

An ontology requires a specific vocabulary that describes a domain and a set of logical axioms that will guarantee the meaning that is desired for the vocabulary terms. This implies that two ontologies can be different in their vocabularies referring to the same domain of knowledge.

The organization of concepts and semantic integration for interoperability between systems is done via ontologies, which contextualize the data and give it meaning. If an EHR records that a certain patient has "allergy", this means that this data has the same meaning as the term "allergy" in the ontology, implying a correct and consistent mapping between data from the information models and the terms of the ontology (Cannoy; Yier, 2009).

As for terminologies, the **application of ontologies to the domain of EER** can make them logically more coherent and intuitive to common sense, even if they are aimed at interpretation by *software* (SMITH; CEUSTERS; TEMMERMAN, 2005).

SEMANTIC INTEROPERABILITY IN RES: THE OpenEHR standard

Making electronic health records interoperable is, according to Chen (2009), a prerequisite for supporting more and more distributed health systems. To this end, it is necessary to arrange PEP/EHR systems, capable of sharing clinical data, through the use of a **reference model, clinical data structures and terminologies, preserving the existing semantics in the knowledge domain**, updating and retrieving data consistently, without ambiguity.

Within this context and objectives, the OpenEHR standard is presented, according to Leslie (2007) aiming to "enable the semantic interoperability of health information between, and within, EHR systems – all in a non-proprietary format, avoiding the holding of rights by suppliers" (LESLIE, 2007, p.51).

Noting the need for a robust theoretical basis for clinical information models, and aiming at requirements such as interoperability, computability, scalability, economic feasibility and performance, an ontology was used to develop the formal basis of the OpenEHR model.

THE GENERATION OF INFORMATION IN CLINICAL AND BUSINESS PROCESSES

The ontology of clinical information described by Beale (2007), the basis of OpenEHR, starts from two types of process: the clinical process that describes the interaction between the clinical investigation system and the system that represents the patient; and the business process, which contains the clinical process and is inserted in the administrative context.

Aiming at the serialization and exchange of messages between information systems, Beale (2007) will present the types of information that can be created in the processes previously described.

Figure 1 - Information Created by the Clinical Investigator

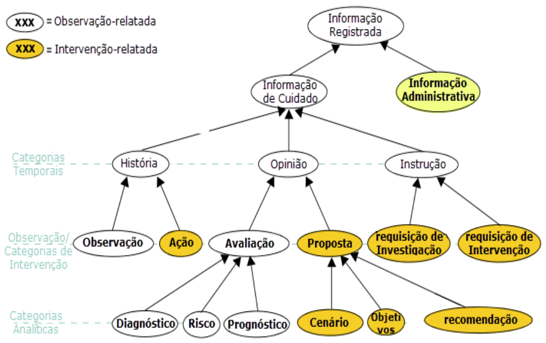
Source: Translated from Beale (2007)

Thus, five distinct types of information can be created during the patient care process: observations, information created by an act of observation; measuring, questioning, or testing a patient or related substance (e.g., urine or tissue); opinions, inferences made by the researcher; instructions, instructions based on observations; actions, registration of intervention actions occurred via instructions or other cause; administrative events, record of events that occurred in the administrative context.

THE CIR ONTOLOGY AND THE REFERENCE MODEL OF THE OPENEHR STANDARD

Based on these categories, Beale (2007) proposes an initial ontology, which aims to situate the types of information presented in relation to the categories of administrative *information* and *care information*, plus necessary categories (Beale, 2007), called **clinical information ontology** or CIR (*Clinical Investigator Record*) ontology), as shown in Figure 2:

Figure 2 - The Ontology of Clinical Information (CIR)



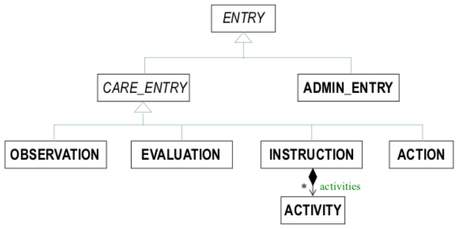
Source: Translated from Beale (2007)

The CIR can be categorized as an information ontology, which deals with any type of information, entities that are committed to some type of medium such as written, audiovisual, etc. In short, something from reality that is being recorded and has characteristics such as the type of registered entity, grades, test results, diagnoses, structure of the records made, relationships between recorded information, etc.

Thus, the CIR ontology, the basis of the ENTRY class (entries) of the OpenEHR standard, is defined to deal with information, more specifically health information. The most important point about the archetypes, built from it, is that they are not descriptions of real things, but records of something that health professionals, by their experience or following a standard procedure, deem necessary to record. Thus, guided by the CIR, health professionals, when recording information via forms, will do so in a more intuitive way, as the categories defined therein correspond to information generated during the workflow of these professionals.

The CIR ontology provides **the basis for the Entry classes of the reference model defined by the OpenEHR standard**, with the main characteristic of being a **generic model**, which represents health care information, but without the semantic specification of particular clinical concepts. Schematically, the conceptual hierarchy defined in the CIR ontology begins with an abstract superclass called *ENTRY*, followed by two subclasses responsible for the entries for **administrative information** (*ADMIN_ENTRY*), as well as **medical care** (*CARE_ENTRY*) followed by four subclasses corresponding to the categories explained above when it was presented, i.e., **observation, evaluation, instruction, and action** (Figure 3).

Figure 3 - The ENTRY Superclass, Based on the CIR Ontology



Source: Beale (2008)

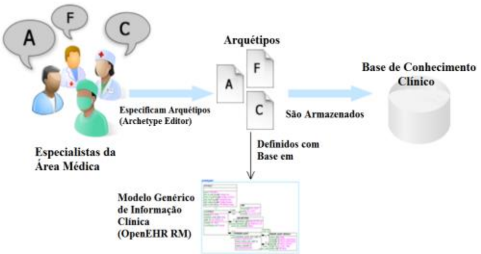
Since the OpenEHR reference model is generic, how will specific clinical concepts such as the patient's blood pressure be represented? In the information models seen, there is no specific class to represent blood pressure, but there is a class that has the clinical concepts to express measurements about the patient: the class (subclass of ENTRY) observation (OBSERVATION). Therefore, blood pressure will be defined as an observation. But then the question arises: how to express the particularities of this observation? The answer to this question will lead to the knowledge model proposed by the OpenEHR standard, or archetype model.

THE KNOWLEDGE MODEL OR ARCHETYPE MODEL OF THE OPENEHR PATTERN

Taking as constituent elements the clinical information models, which allow the representation of general clinical concepts, we arrive at the **knowledge model** of the OpenEHR standard, which aims to represent particular clinical concepts (unlike the reference model, which represents general clinical concepts and resides within the software).

Particular clinical concepts are represented as a set of constraints on the generic information model. The OpenEHR approach, through two-level modeling, enables the medical staff to determine the characteristics of the health record that are most appropriate for their needs, illustrates the separation between the activity of domain specialists (in this case, in particular, the medical field) in the creation of archetypes through the generic information model and that, in turn, they will compose the clinical knowledge bases as shown in Figure 4.

Figure 4 - Construction of Archetypes by Medical Specialists



Source: Translated by Gutiérrez and Carrasco (2013)

Described from the perspective of restriction to the objects of the reference model, the archetypes can be seen according to Martínez-Costa *et al*.:

> The reference model represents the global characteristics of the health record notes, how they are aggregated, and the information context required. This model defines the set of classes that form the generic building blocks of the electronic health record and contains the non-volatile characteristics of the electronic health record. [...] Archetypes apply constraints to objects, which can be considered descriptors of the ontological levels of the domain, defined in a reference model. The archetypes bridge the gap between the generality of the concepts defined in the reference model and the variability of clinical practice, thus becoming a tool to represent these concepts (MARTÍNEZ-COSTA *et al*., 2009, p.151).

The **archetype model**, therefore, can be seen as **a metadata representation** developed to organize and standardize data from knowledge domains. Through archetypes, clinical concepts are captured structurally **outside** of the *software*.

By developing the EHR as a knowledge-based system, a robust application is obtained, easier to maintain and modify, whose knowledge is added via archetypes, which are the computable expression of a domain-level concept in the form of structured constraint statements, based on some reference information model.

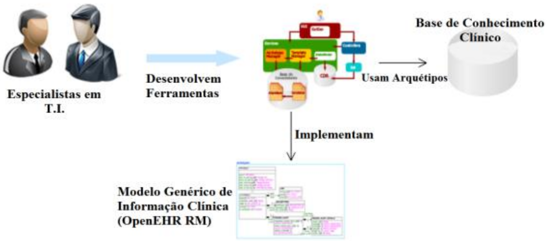
Archetypes can be described as a formal and, at the same time, reusable model of a concept belonging to a given domain that, once represented by an archetype, can be used again in various scenarios that require its application.

From the point of view of **semantic interoperability**, the archetype model can be understood as specifications that seek to ensure the semantics of the information exchanged between the different EHR systems, allowing the incorporation of knowledge into the system directly in the domain model, making semantic interoperability feasible in the exchange of information between EHR systems.

According to Beale (2007), the Reference Model corresponds to the information layer while the Archetype Model formalizes the bridge between the information model and the knowledge model. The most elementary type of distinction in any system model is ontological, that is, at the level of abstraction of the description of the real world, since all models carry some kind of semantic content. **The knowledge model**, therefore, **positions the system at the ontological level**, that is, at the level of abstraction of the description of the real world, since all models carry some kind of semantic content.

The greatest expectation is the possibility of **reusing** the complex structures of information registration, created by domain specialists. Once the archetype repositories have been created, they can be used by information technology specialists to create EHR programs (Figure 5) respecting the division proposed by the dual model.

Figure 5 - Construction of Applications by IT Specialists



Source: Translated by Gutiérrez and Carrasco (2013)

In addition to fostering greater reuse of knowledge, the use of archetypes can be seen as a possible solution to the heterogeneity of health information. Since they promote the separation between processes and data, they make systems more flexible and interoperable. Thus, EHR systems based on the archetype model can be constantly updated under the most direct supervision of medical teams, even without generating interruptions in the system.

RESULTS

IMPLEMENTATION OF THE OPENEHR REFERENCE MODEL ON THE PYTHON PLATFORM

In the architecture proposed by the OpenEHR standard, the reference model is responsible for the semantics of the information that will be worked on via constraints in the knowledge layer (BEALE, 2002). Thus, through the implementation of the information models defined in the reference model, it is possible to express clinical information according to the OpenEHR semantics in the different software development platforms. In the specific case of this research work, the Python platform was chosen.

The result of this effort was positive, the [5] reference model of the specification was implemented in Python, which constitutes the first level of the dual model, proposed in *the design* of the OpenEHR standard. Thus, it is possible to categorically state the possibility of expressing clinical information according to the OpenEHR semantics on this platform.

Obtaining such a result opens the possibility for information systems developers, as well as for academic projects, to write codes in this language, and to express a clinical model capable of creating and using clinical data in accordance with such semantics.

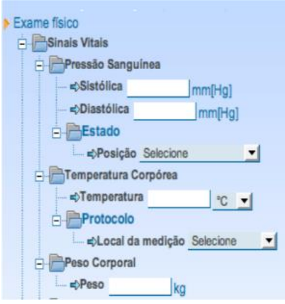
FEASIBILITY AND GAINS OF INFORMATION MANAGEMENT OF AN OPENEHR RES, VIA CMS

Once the certainty regarding the expression of OpenEHR semantics in Python was obtained, the cost-benefit and the challenges that may arise when following a proposal for implementing EMR and EHR software from "scratch" was analyzed, such as the architecture proposal for a five-tier system ("5-tier *System Architecture*") defined by OpenEHR (BEALE; HEARD, 2008).

As seen in section 6, the reference model defines the structure and semantics of clinical information, while archetypes apply constraints to the classes of the reference model to arrive at the concepts or knowledge artifacts defined by clinical experts. Such artifacts, when used by *templates*[6] , allow the entries of electronic medical records to be shaped (Figure 7).

Figure 7 - Representation of Archetypes in the Form of a Tree

[5] *Templates*: These are templates aimed at formatting and facilitating the entry of data into a system.
[6] *Multi level healthcare Information Modelling*. Página Institucional:< http://mlhim.org/>.



Source: Nardon and France (2008)

Requirements Needed for the Implementation of an OpenEHR EHR PEP

To build systems like the one in the illustration above, in addition to the serialization of *compositions* and archetypes, coding of business rules in some programming language, there is a need to use resources, such as component libraries for the visual user interface and orm *frameworks* (in the case of object-oriented languages and relational databases), among others.

The OpenEHR standard also foresees, among several requirements, the need for an *ADL parser*, which transforms archetypes into ADL (*archetype description language*) for the format of objects in memory (OpenEHR, 2013). To perform the reverse path (from objects to ADL), it is necessary to implement an ADL serializer, which starts from the archetypes in the AOM format of memory, for the textual representation in ADL. According to Chen and Klein (2007): "[...] Such a procedure is often used before an archetype is stored and transmitted between systems."

The components described above can be considered as an essential part of a *software* for clinical information management, in the case of implementations that follow the computational architecture proposed by the OpenEHR standard. In view of the functionalities required by such systems, the question can be raised: would there be a need to build such *software* always following the same requirements? Or, there would be the possibility of using a *systemic framework* that, in addition to adding value to *RES/PEP-type software, would avoid the recurrent drop in problems such as* circular import in the implementation of the ARCHETYPE class, described by Kobayashi and Tatsukawa (2012). Such a framework should allow implementation according to the desired characteristics and specific needs, saving the time/effort of coding from scratch.

The need to research solutions for the implementation of the OpenEHR standard, in a line of research, harmonious with the work developed in this research, is highlighted by Gök (2008, p 50): "[...] over time the approach of the OpenEHR standard has matured, however, there is still a gap in knowledge of how to create a system based on OpenEHR (implementation and migration strategies)".

Clinical Knowledge Management via Content Management

There is, in an EHR, the need for an architecture designed to deal with **data** and manipulate **information** at a level of complexity and granularity natural to clinical information. According to Velde and Degoulet (2003, p.108): "The granularity of clinical/health statements varies from text orientation (unstructured), through section orientation (semi-structured), to content-oriented structures (codified)". In this highly complex context, Arancon *et al* highlight content management systems such as:

[...] applications devoted to managing content, documents, and information, structured in such a way as to allow users easy access to knowledge and addition or modification of data. Currently, different solutions are available for such purposes, under categories such as Content Management Systems (CMS), Document Management Systems (DMS), *wikis*, dynamic web portals, search engines, etc. (ARANCON *et al*., 2008, p.245).

A CMS will have features such as ease of content creation and editing by non-technicians, access security, structured workflow in the process for content approval, content versioning and archiving, content*management* to generate consistent outputs, content management, content accessibility, and cost reduction. (Boukar, 2012), (Boiko, 2005) and (Suh, 2003). For a specific situation in the health area, Mooney and Baenziger (2008, p. 70) note that: "a CMS can provide an attractive alternative to the use of expensive laboratory information management systems, by enabling the development of its own web infrastructure".

The detailed analysis of the requirements of the EHR system (Beale *et al*., 2008) and the functionalities of the CMS's brought the realization that characteristics of the OpenEHR reference model, necessary for the archetypes, can be implemented through the use of the structure of a CMS (Boiko, 2005).

An identical situation occurs with the need, in an ideal electronic medical record, to have an intuitive interface that models the natural habits of physicians for entry, information review, and adaptability. As well as providing easy entry of detailed patient information, intuitive interface prototyping , less expensive and advanced *workflow*. CMS's meet these requirements, enabling a reduction in paper use, as well as reducing the documentation load. (LUSK, 2002, p.1227)

From the characterization of the CMS's above, it can be seen that they are inserted in **Information Science**, more specifically as **information management systems**. This finding is corroborated by Han (2005, p.356) when he states that: "[A] ideal CMS is an information management system that preserves, organizes, disseminates and manages locally developed documents and external documents with associated metadata".

Thus, when seeking to position the EHR systems in the domain of content management systems, they could also be positioned in the information management, that is, in Information Science.

CONCLUSIONS

Initially, the research sought to enable, through the implementation of OpenEHR in the Python platform, mechanisms that enable semantic interoperability in RES/PEP systems built on it. Next, the same is done in the light of the effort in the search for a *systemic framework* that enables the representation of clinical information, in the face of an implementation "from scratch". This analysis takes place from the perspective of the specificities of content management systems or CMS.

Research involving a broad subject such as semantic interoperability in health record systems could include such varied considerations and trajectories that a salutary measure at the beginning of the work was to delimit the scope of the problem to be addressed. The proposal adopted was, after an exhaustive study of the OpenEHR specification, to verify how to make it possible to express knowledge artifacts or archetypes in the Python programming platform.

The perception provided, in this case, by the dual modeling made it clear that, before obtaining the expression of OpenEHR knowledge artifacts, belonging to the **knowledge layer**, it would be necessary to verify that the elements of semantics contained in the information models of the **information layer** could be expressed in this same platform.

Such verification, prior to the implementation of the knowledge layer, is crucial for the claim to express clinical information on any platform, because every knowledge artifact, or archetype, is "constructed" from instances of the classes defined by the information models.

In short, using the classes of information models, an unlimited number of archetypes can be constructed. In fact, these classes represent the global characteristics of the components of the health record. It defines the set of classes that form the generic building blocks for constructing the RES.

After the effort of studying the specification, adapting to the chosen platform and coding (in increasing order of complexity of the classes of its various information models), the objective was achieved in order to categorically affirm the possibility of expressing clinical information (in the OpenEHR standard) on the Python platform.

Such a result not only paves the way for the use of OpenEHR archetypes in the

Python platform, but also for knowledge artifacts of patterns that use, or may use, the OpenEHR reference model. This is the case of the *Multi-Level Healthcare Information Modelling* or MLHIM[7] standard, whose equivalent to the archetype is called "Concept *Constraint Definitions"* or CCD, and which uses the reference model of the OpenEHR standard.

Once the result that allows the expression of the reference model in the Python platform was obtained, a context analysis was carried out that would involve the main requirements of a possible implementation from scratch.

As future works, it is presented as a natural development of the research the implementation, in the Python platform, of the demographic information model[8], which is an essential part of the OpenEHR standard and allows the insertion of demographic content in the created archetypes, as well as their knowledge model, or archetypes. The same can be said for the tools required for *the parsing* of ADL files and for the generation of objects in memory as specified by the *archetype object model* or AOM proposed by OpenEHR (Pessanha, 2014, p. 109-110).

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[7] OpenEHR Demographic Information Model Specification: <http://www-test.openehr.org/programs /specification/releases/currentbaseline>
[8] OpenEHR, pagina institucional: <http://www.openehr.org/pt/home.php>

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