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Steps towards an Healthcare Information Model based on openEHR

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Abstract

During COVID-19 pandemic crisis, healthcare institutions globally were experiencing a VUCA - Volatile, Uncertain, Complex, and Ambiguous - environment. Efficient clinical and administrative management had never been so emergent. To achieve this goal, different components of the Healthcare Information System (HIS) must cooperate and interoperate flawlessly. Data standardization is a necessary step towards normalization and interoperability between existing Legacy Systems (LSs), and provides for longitudinal, highly reliable and persistent Electronic Health Records (EHRs). The openEHR standard was chosen for its overall dual domain architecture, where the more dynamic clinical information model may evolve independently from the relatively stable Reference Model (RM). Its Information Model (IM) comprises demographic, administrative and clinical systems. Critical clinical terms have been aligned to the FHIR HL7 standard, as to further support interoperability.

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1. Introduction

Real-life HIS often consist of a complex tapestry of several distinct software products. This complexity arises from successive, niche-oriented software acquisitions that occurred through a continuous and long process of digital transformation in healthcare. Moreover, the choice of new software seldom took into account existing standards, as per the lack of explicit national or institutional directives. As such, different HIS components represent common data in distinct ways, compromising semantic interoperability. To define and implement a consistent information model (IM) in an healthcare institution, one must analyze and remodel data of clinical, demographic, and administrative domains, without disrupting presently used, soon-to-be LSs. In addition, the information access management seems to be always a difficult task, due the high dimension of some healthcare organizations, their internal governance and

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with a lack of adequate representation of roles and capabilities in LSs. All these issues compromise the Information Technologies (IT) potential to help daily clinical practice and knowledge production, and limits our ability to deploy reliable Clinical Decision Support (CDS) systems [1, 10]. Clinical data, besides its main purposes of supporting decisions support continuity of care , serves several secondary uses (e.g. medical and academic research and business intelligence). Although secondary, these uses are considered critical for continuous improvement in the delivery of health care. It's important provide for the ongoing addition of new data sources, as wearables, patient reported data or external systems. Therefore, it is of uttermost importance that distinct data representations are transformed and integrated according to a common data model [9, 3, 6].

1.1. Interoperability and the Use of OpenEHR Standard

Data Quality (DQ) must be ensured throughout all exchanges and modifications, ensuring its range, format, value set, occurrence, and cardinality. The openEHR standard has already proven its value and adaptability in several rapidly changing settings [15, 8]. It consists of a two-level information modeling methodology, where the clinical data model is developed in a different layer from the reference model, separating clinical and technical concerns and allowing for more independent developing of each of these domains. In the clinical domain, the Clinical Information Model (CIM) defines clinical concepts as standardized and reusable units. The main goal of CIM is to provide information consistence - thus allowing semantic interoperability (SI) - using 'archetypes' as building blocks. These, in turn, are used to model more complex structures, called 'templates'. These templates can be easily adapted to a specific clinical setting by reusing existent archetypes and through building of new ones for the representation of concepts that weren't previously modeled accordingly. Standardization and the building block philosophy are particularly useful in healthcare settings, where the participation of experts from each of the several domains is essential for conformance of data visualizations and data entry forms to the specific setting. On the other hand, technical integrity and coherence are ensured through the, allowing, for example, to collect information of those who registered certain information, as well as the system where the registration was made [1, 10, 20, 21, 17, 16]. Thus, the RM embraces a set of classes that define the generic structure of a patient's electronic health record (EHR), context and audit details, all versioning specification, access to a archetypes data via *LOCATABLE* class, and datatype definitions. Fig. 1 shows the main components and subcomponents necessary for the development of an HIS based on openEHR [14, 2].

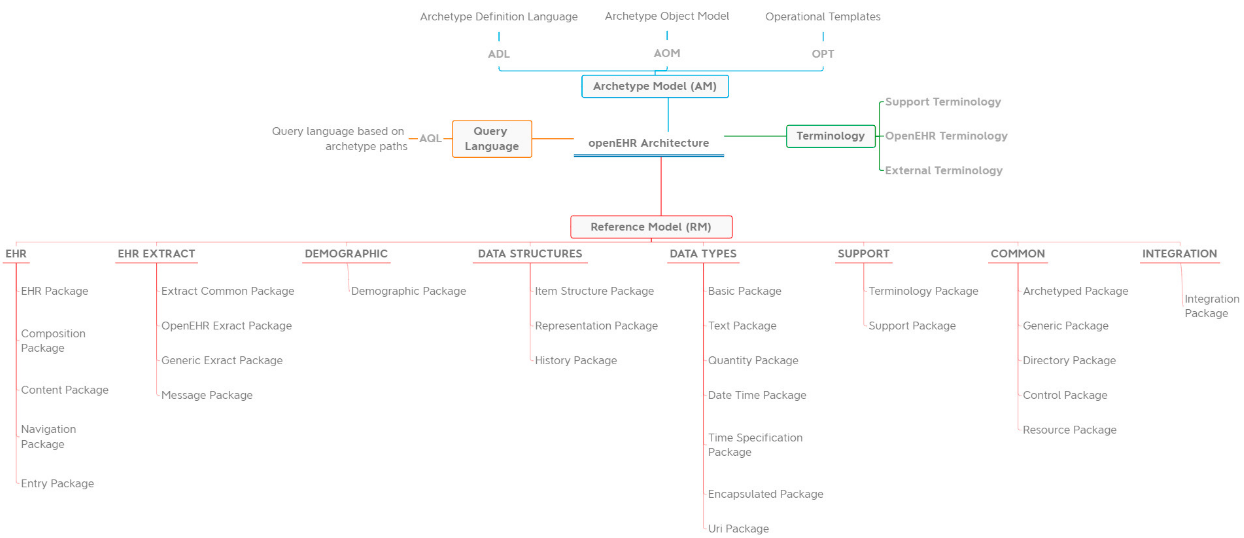

Fig. 1. OpenEHR architecture main components.

2. Related Work

When reviewing literature, several case-studies presenting openEHR based solutions for specific settings and/or use-cases can be found, but few elaborate on using it as the foundations of a EHR. This may be due to the fact that the openEHR clinical domain defines essentially a modeling methodology (and open-source tools) and a shared repository for community-built information model artifacts (archetypes and templates). It's meant to be flexible, and thus provides guidelines, while relatively lacking orientation on how to implement, the best database technologies to use, or backend and frontend user interfaces. Most papers focus on modeling clinical records, then adapting their LS to integrate the modeled information. In other words, most published works use openEHR as the backbone of specific settings systems.

Afef S. Ellouzea, Sandra H. Tlilia, and Rafik Bouazizb developed a new methodology for generating interfaces based on openEHR archetypes called *OpenEHR modeling Methodology (OpenEHR-MM)*. In their study, the researchers refer that *"the archetype model for this modeling approach allows only the definition of the clinical data structures and does not contain information to specify how these structures must be adapted to the user context"*. In this new approach, the RM archetype package was extended in order to support knowledge related to the presentation and content of the data returned, according to a certain context [18].

In terms of IT infrastructure flexibility, Debbie Tarenskeen *et al.* defend that the Conceptual Independence (CI) contributes to flexible data models that are independent of the application side. Their study was performed through the use of mixed-methods research in 10 healthcare organizations, where five of them have implemented openEHR. This research was motivated by a research question: *"How do implementations of CI in information systems lead to an increase in flexibility in organization-wide IT infrastructure?"*.

Their conclusions demonstrated that openEHR-based systems have a greater capacity for change and remodeling. In addition, these organizations have shown a positive effect on the reuse of functionality and modularity. Some organizations mentioned that they already have even implemented almost all openEHR modules. The following table shows the mean score of each parameter evaluated in organizations [19].

Table 1. Results of IT infrastructure flexibility questionnaire by Debbie Tarenskeen *et al.* [19].

Evaluated subjects	Others Organization	OpenEHR Organizations
Modularity		
ISs Modular	2.8	5.3
Rapid Changes	2.3	5
Functionality quickly added	3	4
Modifying components	2.8	3.4
Minimal unnecessary	5	4.8
Loosely coupled	5.3	3.2
Transparency		
Remote users	6.0	6.4
Transparent access	4.0	6.2
Applications across multiple platforms	3.0	5.6
Data easily used in other systems	2.4	4.9
Multiple interfaces or entry points	3.0	5.6
Standardization		
Corporate rules and standards	5.8	6.3
Standardized data to be shared	3.2	5.4
Electronic links to external parties	2.9	5.1
Highly interoperable	3.3	4.4
Compliance guidelines	4.1	5.4
Scalability		
Compensate peaks	5.7	5.6
Information system scalable	4.7	5.8
Sufficient capacity for additional	5.8	6.2
Business needs	3.3	6.0
TOTAL	**3.9**	**5.2**

The adaptability, reuse, and modification of openEHR systems is clear, and the proof of this are the various case studies developed during the COVID-19 pandemic. In such a short time, agile processes were achieved and developed that allowed the improvement of clinical practice in healthcare institutions around the world [7, 13, 4, 5].

3. Information Model Architecture

The development of a new IM architecture was part of a project by the University of Minho in partnership with the *Centro Hospitalar Universitário do Porto* (CHUP) healthcare institution. Some works have already been developed by this project and published with the scientific community [2, 13, 12, 11].

The IM was designed and subdivided into the Demographic Information Model (DIM) and the Clinical Information Model (CIM). Before developing the retrieval algorithms to collect the clinical information of patients, it was necessary to define them as 'persons' and 'patients' of the institution. Consequently, it was necessary to model the entire DIM of the institution, namely its organizations, teams, roles, relationships, and associated persons. For this, some templates were modeled based on demographic domain archetypes, in order to take full advantage of the openEHR RM. The knowledge modeled in the AOM is as valuable as the RM that supports it, since most of its classes inherit from the *LOCATABLE* class. Through this class, it's possible to feed the RM, managing to combine clinical or administrative data with registration and audit information in the system.

3.1. DIM Modeling

Templates were modeled using the Archetype Designer platform, developed by Better. These templates are based on demographic archetypes in order to take full advantage of RM structured knowledge. Some archetypes presented in various international Clinical Knowledge Manager (CKM) instances were reused and adapted, while others have been developed for the team. Table 2 contains all archetypes and templates used and developed to construct the DIM.

Table 2. Templates modeled in OpenEHR and the archetypes reused.

Template	Archetypes
Organisation.opt	openEHR-DEMOGRAPHIC-ADDRESS.address.v0 openEHR-DEMOGRAPHIC-ADDRESS.electronic_communication-provider.v0 openEHR-DEMOGRAPHIC-ADDRESS.electronic_communication.v0 openEHR-DEMOGRAPHIC-PARTY_IDENTITY.organisation_name-CHUP.v0 openEHR-DEMOGRAPHIC-PARTY_IDENTITY.organisation_name.v0 openEHR-DEMOGRAPHIC-CLUSTER.provider_identifier_chup.v0 openEHR-DEMOGRAPHIC-PERSON.organisation_demographic.v0 openEHR-EHR-CLUSTER.telecom_details.v0
Care_team.opt	openEHR-DEMOGRAPHIC-ADDRESS.electronic_communication.v0 openEHR-DEMOGRAPHIC-PARTY_IDENTITY.team_name.v0 openEHR-DEMOGRAPHIC-PERSON.care_team.v1
Person.opt	openEHR-DEMOGRAPHIC-ADDRESS.address.v0 openEHR-DEMOGRAPHIC-ADDRESS.electronic_communication.v0 openEHR-DEMOGRAPHIC-PERSON.person.v0 openEHR-DEMOGRAPHIC-ITEM_TREE.person_details.v0 openEHR-DEMOGRAPHIC-PARTY_IDENTITY.person_name.v0 openEHR-EHR-CLUSTER.telecom_details.v0
Role-team_member.opt	openEHR-DEMOGRAPHIC-ROLE.team_member.v0 openEHR-DEMOGRAPHIC-CAPABILITY.individual_team-functions.v1
Role-organisation_member.opt	openEHR-DEMOGRAPHIC-ROLE.employee.v0 openEHR-DEMOGRAPHIC-CAPABILITY.individual_credentials.v0
Role-organisation_patient.opt	openEHR-DEMOGRAPHIC-CLUSTER.person_identifier.v0 openEHR-DEMOGRAPHIC-ROLE.patient.v0

3.2. DIM Architecture

In order to have a demographic and administrative management area, the templates were developed both for information retrieving and for the future maintenance of healthcare organization structure.

For the maintenance and creation of new organizations, as well as work teams, performed roles, and professionals associated with them, it was necessary to develop the following architecture present in Fig. 2.

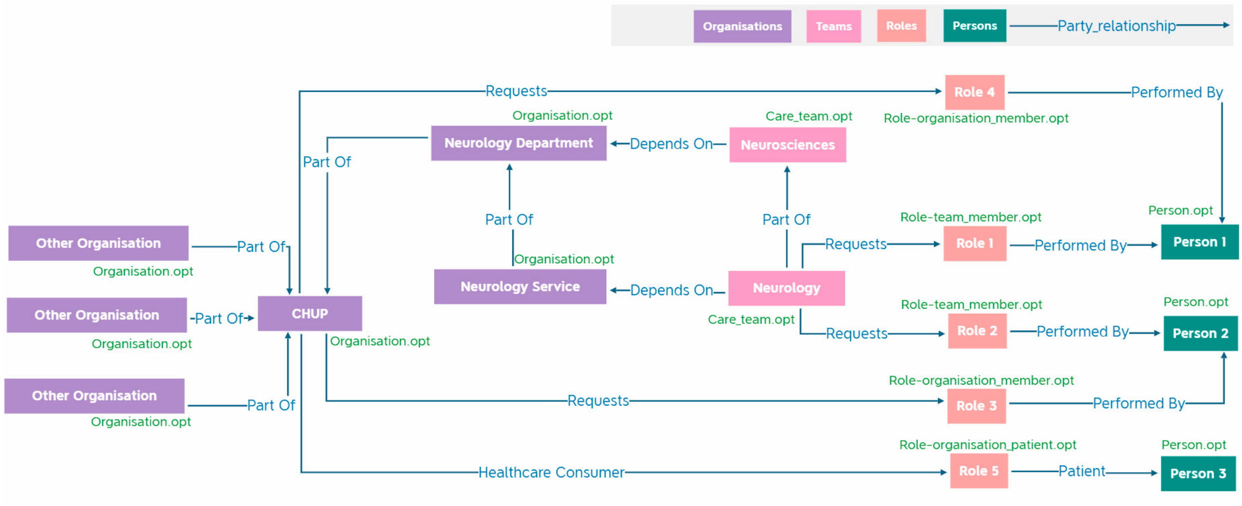

Fig. 2. Demographic Information Model architecture.

Each entity - organization, care team, role, person - is supported by its respective modeled structure, and they interrelate with each other through the RM *PARTY_REF* class with different meanings. The team decided to completely separate the entities in order to have greater control over each one, using the potential of the *PARTY_RELATIONSHIP's* RM.

Through this architecture, the existence of a hierarchical structure from the main organization (CHUP) can be detected, to its underlying and dependent organizations. CHUP is also subdivided into departments, with different services associated with it, and each of these services is linked to different care teams in different contexts.

One of the most important decisions was how to model the patient, the institution's employees, and the member of each care team. Only one person structure was developed that feeds the identification of the subject regardless of their type of relationship with the institution. It's clear that these relationships are defined separately and related to their source and target through roles. These roles have certain associated capabilities that intrinsically define the credentials of a specific role.

4. Conclusions and Future Work

Increasingly, agility, flexibility, interoperability, and standardization are fundamental characteristics in the developed IT systems, mainly in terms of IT systems in healthcare. The healthcare institution targeted by the present case study, until now, needed several LSs to manage each entity of the demographic system. The difficulty of interoperating between these LSs was one of the motivations for the development of a solution based on a standardized and distributed architecture. The institution will adapt the OpenEHR standard in other aspects, both to the demographic level and to the clinical level. The next step will be the development of the patient's EHR through the EHR package, associating his compositions as contributions to the system. In addition to the contributions, states, permissions, and types of access to certain clinical information will also be taken into account. At the same time, the versioning system for each of the supramentionated classes will be implemented.

For all that has been said before, the power of this standard's modularity is remarkable, allowing institutions to gradually shape themselves.

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