An Approach for Modeling Annotation in the e-Health Domain

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Abstract. In our research, we established a medical annotation model in the form of an ontology in an effort to ensure data interchange amongst medical annotation systems. We employ the "patient partner" approach to involve the patient in the medical annotative activity. In fact, the patient will be able to register, annotate, and comprehend the comments made in his medical file utilizing this new paradigm.

Keyword: Annotation · Medical record · Interoperability · Patient · Ontology

1 Introduction

Over the last two decades, health information systems have experienced a significant technological revolution, which has affected the quality of services provided by these systems, their functionalities, the extent of their applications, and the sorts of users that use them [1].

As a result of this transformation, the Electronic Medical Record (EMR) is one of the components of medical information systems that are being transformed. It is true that with the use of ICT (information and communication technologies) in the medical area, the medical record, which was previously on a physical medium, has now been converted to a digital version. The latter is defined as an electronic statement that contains a summary of treatments, diagnoses, and patient follow-ups, as well as any written communications between healthcare specialists [2].

Currently, scientific research is seeing a slew of initiatives to include the patient in the decision-making process along his treatment course. This is beneficial to the healthcare worker, the patient, and the whole healthcare system because it encourages collaboration, cooperation, and knowledge exchange, and it contributes to an improvement in the safety and quality of treatment. Patient participation in the healthcare system is focused on a variety of levels, including acquiring medical knowledge, educating, establishing the treatment protocol, providing direct care, organizing care, and so on [3].

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In this study we will investigate the applicability of the patient partner approach to the area of computerized medical record annotation. Indeed, traditionally held and examined solely by a medical team in a single health establishment, local electronic medical files are now shared and consulted by new interveners, the hosts, and the patients. An important part of the host's job is to create an application that includes both patient care and data preservation. Electronic medical records cannot be created or accessed without a patient's agreement or authorization. Furthermore, he is entitled to see his medical records as well as papers pertaining to the diagnosis and treatments that are relevant to him. In this sense, the patient should also have the right to comprehend the annotations that have been made to his medical record.

A medical annotation is, in reality, a comment that is written in the patient's medical file for a particular purpose. In this case, it is done by the healthcare practitioner and is meant to be read by another healthcare professional or by the patient themselves. As a result, we can say that medical annotation is a fundamental part of the healthcare system. She is the one who encourages open dialogue and information exchange among the many parties involved. However, a review of the literature on numerous annotation systems revealed that all of these techniques remain basic and are not widely used in the health system [4]. Patients are unable to access the content of the annotation systems examined in the literature, they are unable to communicate their ideas in a meaningful manner, and as a consequence, the annotation is unable to promote collaboration among various stakeholders. It will cease to work properly, resulting in a breakdown of communication between healthcare practitioners and patients.

Each annotation system investigated in the literature has its own set of standards and conventions. The inability to integrate diverse programs prevents data interchange across applications. Due to trade blockage, a healthcare professional cannot communicate or receive data from peers or transfer information across systems. This restricts the movement of both patients and healthcare providers. Also, the patient cannot send personal data to his doctor or a health practitioner, resulting in data loss. Indeed, this highlights the need to address the challenge of interoperability among different annotation systems. The objective of this work is to develop an ontology that ensures the semantic layer of interoperability.

So, what follows is an attempt to answer a fundamental question:

What generalized model of medical annotation should we use to promote health professionals and patients to exchange annotations in electronic medical records?

The second section of this paper provides a comprehensive understanding of the different types of medical records and highlights the crucial importance of facilitating their sharing.

The third section delves deep into an extensive exploration of the diverse definitions of annotation found in the literature. This thorough analysis captures a wide range of perspectives offered by researchers in the field.

The fourth section introduces a meticulously developed ontology specifically designed for layered annotations within the medical record. This ontology serves as a robust framework that ensures semantic interoperability across various medical

annotation systems. By standardizing the annotation process, this ontology significantly enhances data exchange and promotes seamless collaboration among healthcare professionals.

The fifth section is a conclusion that presents a comprehensive summary of our findings while also providing valuable insights for future research in the domain of medical record annotation.

2 Computerization of Medical Record

- **Medical record sorts**

  A patient's medical record is defined as a statement that contains a summary of treatments, diagnoses, and patient follow-ups, as well as any written interactions between health care providers.

  Examining various forms of medical data gives critical information for medical annotation modeling. It makes it easier to interpret medical data, identify specific annotation requirements, build suitable annotation schemas, and validate annotations.

  In this part, we will look at the various forms of medical records and highlight their key advantages.
- **The EMR Electronic Medical Record and the CCR Computerized Clinical Record:**

  The EMR and CCR are electronic equivalents of the traditional medical record, which is recorded on paper with a pencil. They are memories that allow the acquisition of personal data from patients [Article 1 of the Canadian Uniform Act on Electronic Commerce]. These files are deemed complete since they contain all of the essential information and specialized words relevant to a given speciality and also create the proper instruments for trade practice.
- **The EMR Electronic Medical Record and the EHR Electronic Health Record:**

  The EMR is distinguished from the EHR by the Canadian Medical Protective Association (CMPA)[1]. The EHR delivers complete information from many providers across numerous provinces and regions. Nevertheless, this sort of record provides less detail than the EMR (it does not contain all the information presented in the EMR). The concept of electronic record sharing arises from the capacity of a health care practitioner to adhere to data generated and kept by someone else. As a result, he may study them and use them within the context of his specialty's practices. He can also contribute information to it. We can look at Quebec, where the QHR (Quebec Health Record) was implemented, and France, where the SMR (Shared Medical Record) was constructed. The medical records implemented in France and Quebec are concrete examples that illustrate initiatives for sharing medical records, aimed at improving care coordination and patient management[2].

[1] Les dossiers de santé électroniques: perspectives de la responsabilité médicale. Aout 2008. p. 5. http://www.cmpa-acpm.ca/cmpapd04/docs/submissions-papers/pdf/com-electronic-health-records-f.pdf. ousur www.cmpa-acpm.ca. http://www.cdpdj.qc.ca/publications/memoire-pl-59-renseignements-sante.pdf.

[2] ASIP Santé, Rapport d'activités 2010. PP 26 et 28. http://esante.gouv.fr/sites/default/files/ASIP-RA2010.pdf.

- **The local EMR and the shared EMR:**
  Local EMRs are used and preserved only by its authors and are entirely their responsibility. Yet, more healthcare personnel have access to shared EMRs, which explains the rise in the number of stakeholders and managers.

The various kinds of medical records are contrasted in the table below (Table 1).

Table 1. Kinds of medical records

	EMR	CCR	QHR	SMR
Owner	Medical clinic	Health institution	Service points participating in the DSQ project	Beneficiaries of health insurance
Content	Information recorded by the clinic's clinicians at the time of the consultation or care episode	Information recorded by the clinicians of this establishment at the time of the consultation or the episode of care	Results of examinations or laboratory analyses, results of imaging exams and medication	Results of biology and radiology reports, general medicine, treatments/prevention, certificates and patient area
individuals withaccess rights	Clinicians and anyone authorized by the patient	Clinicians and anyone authorized by the patient	Authorized professionals, Each authorized professional does not necessarily have access to all parts of the file	The patient chooses which health establishmentor which doctor will be able to have access to his file to consult or supply it

- **Shared medical record actors**
  Local electronic medical records, which were previously held and accessed solely by a team at a single health facility, are now shared and consulted by new stakeholders, the hosts and the patients.

  Host: The Host's functionality entails creating an application that combines processing and preservation of patient data[3,4].

  Patient: the establishment, accommodation, and access to the SMR or QHR cannot take place without the patient's authority and agreement. The latter has the right to see his file, as well as the records pertaining to his diagnoses and treatments, and even to obtain information pertaining to his file.

  Healthcare professionals involved: The public health code mandates that medical practitioners get the patient's permission before consulting their shared EMR. Within the confines of the professional practice of their trade, they are accountable for

[3] Article 19, de la loi sur les services de santé et les services sociaux.
[4] Article L 1111-21 du code de la santé publique.

any confidential information pertaining to the patient. So, they must keep all sensitive information hidden.

- **Contributions of medical record sharing**

  The digital support relating to the medical file is an effective tool which contributes to facilitate the research of the information concerning the patients, to help to process the data and to ensure the storage.

  The table opposite (Table 2) shows the contribution of sharing medical record on an individual and collective level [5–7].

Table 2. Benefits of medical record sharing

Individual benefits	Collective benefits
• The patient's right to view his medical file: the patient's education and culture have a major impact on his consent and fear about his medical care • Decision support and medical mistake prevention: Decision support systems are intended to give clinicians convenient access to test-based medicine and guideline treatments (automated vaccination reminders, for example) • Automation of tedious tasks • Security and traceability needs: the law of traceability requirements for access to information, data security and protection of individual freedom	• Ease of information retrieval: for example the indexing of images by their content and the judicious processing of distributed heterogeneous information • Data and information processing: the medical record includes capabilities for graphically summarizing the patient's state and illustrating the patient's data in the form of complex signs Storage: Paper documents can only be kept for 50 years, thus it's critical to develop the software required for medical data storage • Decreased access, routing, and data sharing times: When several people have access, sharing and exchanging information is made simpler

In this sense, we can state that the share of patient file ensures the efficient operation of the care protocol, helps to raise the standard of medical care, ensures data security, and helps stakeholders coordinate while enabling data access. Also, by allowing the patient access to his medical record, it is feasible to give him detailed explanations of his condition and course of treatment. As a result, both the professional and the patient have a vested stake in the outcome.

3 Annotation of Medical Record

Having a precise understanding of what constitutes an annotation is crucial for accurately describing an annotation ontology. In fact, the definition of annotation has sparked diverse perspectives among researchers regarding this concept. These varied viewpoints have played a significant role in enhancing our comprehension of annotation and have laid the groundwork for constructing a pertinent ontology that encompasses the concepts and relationships associated with annotation. As a result, the annotation ontology embodies a

comprehensive understanding of the annotation concept by taking into account multiple researchers' perspectives.

- Annotation is also referred to as "**the trace of an action**" by researchers. Annotations show that the person who reads a text is engaged intellectually and makes an effort to annotate it [8, 9].
- An annotation may also be thought of as "**a visual shape**" In fact, an annotation must be visible in order to be deciphered [10].
- Annotation is a "**visual shape with a purpose**". It is critical that the annotation serves a function. Nobody annotates for no reason. There is always a motivation for the annotator to annotate.[11]
- Annotation is defined by some scholars as "**a trail of activity in a visual form with a purpose**" Therefore it is a record of the annotator's mental representation on a document for a specific purpose [12].
- The annotation is "**a visual shape connected to a page**" according to [13]. According to this scholar, an annotation must be tied to a document at all costs since if the paper is lost, so is the annotation.
- In the discipline of computer science, we must employ an anchor to describe the placement of the annotation in the document since "**the annotation is a visual form and an anchor**". The annotation is defined in this same field as "**visual form attached by an anchor with a right of access**" Only those who are permitted may annotate a document in this situation [14].
- An annotation, according to some academics, is "**a trail of action in a unified visual form coupled with an anchor**" The mental image that the annotator has created about the target is the annotation, and we use the anchor to tie the annotation to the document [15].

4 Medical Annotation Model

Our objective is to propose a formal model of annotation to aid in the resolution of issues that arise while researching annotation systems [16–18].

In 2001, the W3C released the initial draft of the Annotea standard, which aimed to define an annotation model based on the RDF representation. Over time, this model underwent significant enhancements by the dedicated research team, eventually leading to its official adoption as a standard by the W3C in 2014. Despite the evident success of RDF technology in the semantic web domain, upon which Annotea is built, the adoption of Annotea for annotating systems development has been limited among researchers. To address this issue, researchers [19] developed an ontology that drew inspiration from the Annotea model. We utilized this ontology as a fundamental basis and further refined it to tailor it specifically to the medical field.

Our ontology development followed the established methodology employed at Stanford University, which encompasses seven fundamental steps: Domain definition of the ontology, Reuse of existing ontologies from the literature (if available), Definition of the set of important terms, Definition of classes and their hierarchy, Definition of properties of the classes, Definition of attribute facets, and Creation of instances. By following this methodology, we ensured a systematic and comprehensive approach to ontology development for our research [19].

To effectively illustrate the foundational concepts of our ontology, we can take the example of a radiologist who wants to annotate the medical field of his patient. The radiologist, as an annotator belonging to the medical team, has the patient's consent to access their medical record and make annotations. On a specific date, in a particular healthcare facility, using their PC, the radiologist wishes to write an annotation on a specific paragraph of the patient's electronic medical record. The radiologist uses their PC and connects to the healthcare facility's medical information system, which contains the patient's electronic medical record.

While navigating through the record, the radiologist locates the paragraph on which they want to write an annotation. To attach the annotation to the target paragraph, the radiologist uses an anchor, which can be a feature provided by the medical information system or a dedicated annotation tool. They select the relevant paragraph and access the section reserved for scientific annotations within the document. In this section for annotations, the radiologist writes their annotations to capture the important points. They may provide additional information, observations, interpretations, preliminary diagnoses, or other relevant information related to the content of the paragraph. The annotations are saved in the patient's electronic medical record, typically in a structured format and associated with the corresponding anchor, thereby linking the annotation to the specific paragraph. The objective of this annotation is to retain the important points and provide additional information for future reference. This can help other healthcare professionals understand the radiologist's reasoning, clinical decisions, and evaluations when reviewing the patient's medical record.

The proposed ontology includes the following concepts:

- **Physical attribute**

  Anchor: An annotation's anchor is a way for an annotator to define where the annotation should be placed within the document.

  Content: it is a trace of the mental representation that the annotator has developed concerning the object of interest.

  Target: the target serves as the basis for the annotation. The healthcare professional has the possibility of placing his annotation either in the section reserved for scientific annotations, or in the section reserved for adopted annotations, as the case may be. The patient can keep his notes in a part that has been reserved for him.

  The following figure highlights the subclasses of the physical attributes class
- **Circumstantial attribute**

  Circumstantial attribute encompasses all aspects of contact with the environment (date, place, tool, validity).
- **Partnership Attribute**

  These characteristics arise when many types of stakeholders collaborate together on a project.

  Intervenor: a person who has the authorization of the patient to consult and annotate his electronic medical record is called an intervenor.

  Medical team: in this case, the speaker is a member of the medical profession.

  Non-medical team: the intervener, in this case, is not a health professional.

  Patient: the patient is a practitioner who has the power to take notes in his medical file.

Patient: The patient is entitled to view and make notes in his medical record.

Host: it is the role of the host to create an application that includes both the processing and archiving of patient data.

Patient's family: Electronic medical records (EMRs) can be viewed and annotated by a patient's family members with the patient's permission.

Level of analysis: The term "level of analysis" refers to the process of analyzing the extensive data available on the patient.

Partnership level: the different stakeholders must collaborate in order to reach a consensus on a decision. For this reason, they are required to go through the four degrees of partnership.

Transmission level: this level signifies the beginning of the discourse phase between the different parties involved in the process.

Planning level: at the planning stage, all the different stakeholders work together to plan each step of the care pathway that the patient will go through.

Action level: it is about going to the act of care and implementing all the activities previously prepared.

Informative unit: an informative unit is a collection of information on an illness or medical event that pertains to a patient.

Quantifiable piece of information: for example, the number of hours slept or meals consumed during the course of a day.

Qualitative piece of information: patients' emotional levels or their general health information are examples of qualitative data.

Personalization parameters: they refer to the characteristics that distinguish one patient from another in terms of reading style and annotation generation process. Personalization parameters, as stated in earlier sections, are as follows: (learning level, media preference, language preference, specific requirements, beliefs, social norms, psychological data).

Access authorization: the authority required for a user to have access to protected data or resources in a medical record concerning a certain patient.

- **Semantic Attribute**

  Semantic attributes are the characteristics which make it possible to adapt the annotation to the function to which it applies. They help make sense of annotations by providing context.

  Perlocutionary attribute: an annotation is produced for a specific purpose by the person who makes it.

  Production objective: the objectives of the annotator with reference to the creation of his note.

  Reading objective: these are the annotator's expectations for reading his note.

  Communication object: the communication object identifies the subject of the annotation, ie the subject of reading the annotation.

  Reuse context: the reuse circumstance is a representation of how the annotation was intended to be reused.

The (Fig. 1) illustrates the proposed ontology's class hierarchy.

The class hierarchy view displays asserted and inferred class hierarchies. By default, the stated class hierarchy is shown. The asserted class hierarchy view is one of the

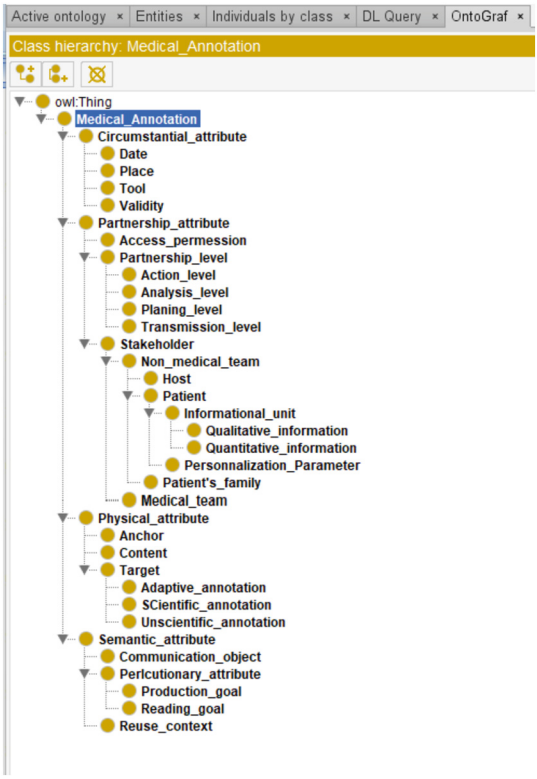

Fig. 1. Class hierarchy

primary navigational features in PROTEGE. It is displayed as a tree, with the nodes of the tree standing for the classes. Sub/super class relationship in the class hierarchy is represented by a child-parent relationship in the tree.

In our ontology, we have the class "**Medical annotation**" is the parent class of the classes "**Physical attribute**", "**Semantic attribute**", "**Circumstantial attribute**" and "**Partnership attribute**" which are sister classes that appear under their parent class "**Medical annotation** ".

"**Anchor**", "**Target**" and "**Content**" are sister classes derived from the "**Physical attribute**" class. "**Anchor**" is the parent class of the "**Scientific annotation**", "**Adaptive annotation**" and "**Patient annotation**" classes. "**Communication object**", "**Perlcutionary attribute**" and "**Reuse context**" are equivalent classes. They are the daughter classes of the "**Semantic attributes**" class.

The "**Partnership attribute**" class is parent class of the classes: "**Partnership level**", "**Access permission**" and "**Stakeholder**". "**Stakeholder**" derives into two classes which are: "**Medical team**" and "**Non Medical Team**". "**Host**", "**Patient's family**", "**Patient**" are the daughter classes of the "**Non medical"** class. "**Transmission level**", "**Analysis level**", "**Planing level**" and "**Action level**" are the subclasses of the "**Partnership level**" class.

(Figure 2) showcases the object properties within the proposed ontology, providing a visual representation of the relationships established between entities.

Fig. 2. Object properties

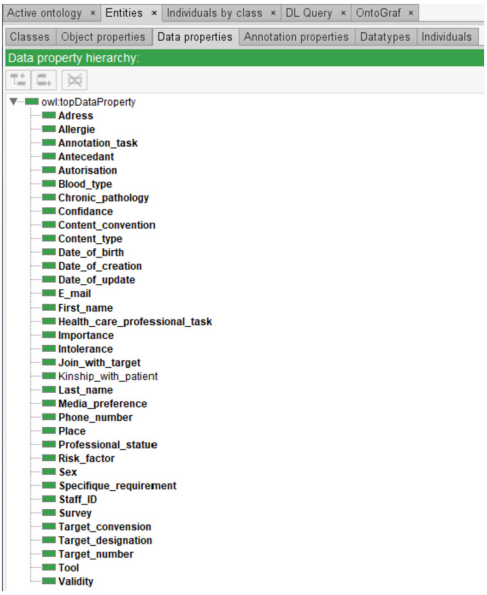

Fig. 3. Data properties

(Figure 3) provides a visual representation of the data properties integrated into the proposed ontology, illustrating the specific attributes and characteristics associated with the entities.

(Figure 4) presents an example axiom for the class 'MedicalAnnotation. This axiom specifies that instances of the class "MedicalAnnotation" must have at least one "PartnershipAttribute", at least one "SemanticAttribute", at least one "CircumstantialAttribute", and at least one "PhysicalAttribute". The quantifier (some) indicates that there exists at least one instance that satisfies the restriction.

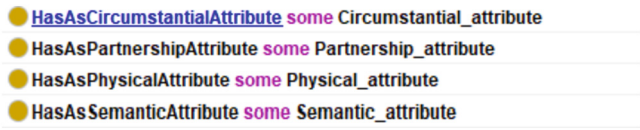

Fig. 4. Example of axiom

5 Conclusion

In conclusion, the development of an ontology for annotation in the medical domain serves the purpose of creating a standardized and structured representation of medical annotations. By capturing the knowledge and semantics associated with these annotations, the ontology enables easier utilization, sharing, and interoperability across diverse applications and systems. The proposed ontology undergoes discussions and validation by domain experts, and it is essential to emphasize that the validation of ontology performance in medical applications is an ongoing process. User feedback and regular evaluations play a crucial role in identifying areas that require improvements and allowing for adjustments to be made to the ontology accordingly. As part of future work, we plan to implement an annotation system based on this ontology, further enhancing the efficiency and effectiveness of medical annotation processes.

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