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Study of Healthcare Annotation Systems

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ABSTRACT

The annotation practice is an almost daily activity used by healthcare professionals (PHC) to analyze patients' records, collaborate, share knowledge, and communicate. These annotations are generated within a healthcare cycle. Similarly, this cycle represents the life cycle of annotations in the patient record. The exponential increase in the number of medical annotation systems made the choice of a system by a PHC difficult, in a well-defined context (biology, radiology) and according to his/her needs to the functionalities offered by these tools. Therefore, the authors propose two taxonomies to distinguish annotation tools developed by industry and academia over the last two decades. The first classification provides an external vision based on five generic criteria. The second classification is an internal vision that gives us an idea about the functionalities offered by these systems. Finally, these unified and integrated classifications criteria are used to organize and observe the limitation of 50 medical annotation tool systems.

KEYWORDS

Annotation, Annotation System, Classification, Competency, E-Health, Health Record, Healthcare Cycle, Healthcare Processes, Healthcare Professionals, Web Service

1. INTRODUCTION

The paper annotation practice is very common. Indeed, during our reading, we are all accustomed to writing our comments in the margin of the document, highlighting or circling part of the text to enrich and add value to information (Khalil Chehab, Kalboussi, & Kacem, 2019; Anis Kalboussi, Mazhoud, Omheni, & Kacem, 2014; Anis Kalboussi, Omheni, Mazhoud, & Kacem, 2015a). Annotation is a central practice in many professions: teachers annotate copies of students; professors' exchange annotated documents during their work; engineer co-builds engines by annotating sketches of plans to make them evolve, doctors' comment on the patient records...etc. (K. Chehab, Kalboussi, & Kacem, 2018; A. Kalboussi, Mazhoud, Hadj Kacem, & Omheni, 2013; Anis Kalboussi, Mazhoud, & Kacem, 2016b). The practice of pencil-and-paper annotation, among healthcare professionals (PHC) in the patient record is common and contributes to the enrichment of knowledge and skills of health professionals (PHC). With the emergence of new information and communication technologies, the field of digital health (Dingli & Seychell, 2014; Yu & Yilayavilli, 2010), also called e-health, has undergone a significant and promising technical revolution over the last decade (Charlet et al., 1998). This revolution allowed health professionals to take full advantage of the computerized medical services by sharing the important data, the necessary knowledge and the key skills in a digital world (Anis Kalboussi, Mazhoud, & Kacem, 2013). Among the applications that are covered by this digital revolution, there are the annotation systems (Dutta, Mondal, & Paul, 2020; Kraljevic et al., 2019; Ma

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& Meng, 2018; Philbrick et al., 2019; Segura et al., 2017) dedicated to healthcare professionals (local application/web application/plug-in) that have been developed to manage digitally the annotations of these latter. Here, annotations can cover different domains of healthcare and can have different types. Moreover, they can be private, public, or shared, according to the annotated content (Bringay, Barry, & Charlet, 2004). As a result, these systems are becoming increasingly claimed and felt by the different medical actors, hence, they offer the necessary means to explain and enrich the information with personal observations and permit ideas sharing which in turn improve collaborative working practices.

In this work, we started with an exhaustive reading for the available papers on annotation systems in general and medical annotation systems in particular. Although the medical annotation systems have already been studied in a variety of contexts (doctor, nurse, biologist, radiologist), yet when it comes to the PHC to choose which system to use based on the functionalities offered by these latter is difficult. Also it is not a trivial task for a researcher he wants to identify future research areas based on existing annotation systems. This is because the annotation systems are so common and many of them share similar objectives which can either be to create annotations or to manipulate them with fairly classic functionalities. Moreover, there are no formal criteria to facilitate the comparison between those systems and to guide PHC choice or a researcher. As a result, there is a fragmented picture of these annotation tools. As far as we know, this is the first work to consider the classification of medical annotation system. The purpose of this paper is to provide a unified idea about the annotation systems used by healthcare professionals. This panoramic view is based on a classification of fifty different annotation systems developed in literature over the past two decades by industry and researchers. The concentration of the difference permits to conclude the classifications criteria and to highlight the challenges in this research field. In this paper, first, the organization of annotation systems is built on the basis of five generic criteria (Azouaou, 2006; Anis Kalboussi, Omheni, Mazhoud, & Kacem, 2015b): standard annotation (computational / cognitive); category of the annotation system (application / plug-in / website); type of annotative activity (manual / semi-automatic / automatic); annotated resource type (text / video / image / doc / HTML / pdf/ etc.) and practitioner that is a PHC. A second comparison is made based on the functionalities offered by the medical annotation systems. Moreover, based on the extensive review of the existing annotation systems we identify the limitation according to the defined criteria.

The rest of the paper is organized as follows: Section 2 gives a general presentation of the annotation systems and a classification of these tools based on several criteria; Section 3 draws some key observations and a discussion of open research problems on annotation systems. Finally, section 4 concludes this paper.

2. ANNOTATION IN MEDICAL SYSTEMS

In the literature, there are several definitions of medical annotation. For example, in (Bringay et al., 2004) health record annotation is seen as "a particular note related to a target. The target can be a collection of documents, a document, a segment of the document (a paragraph, a group of words, an image, part of an image, etc.) or an annotation. Each annotation has content, materialized by an inscription. This is the trace of a mental representation elaborated by the annotator about the target, resulting from a cognitive process located, reading the annotated document. The content of the annotation may be interpreted by another reader. The anchor links the annotation to the target (an arrow, a circled sentence, etc.).". In (Anis Kalboussi et al., 2015b), the biomedical annotation is defined as "a biological interpretation, an enrichment of knowledge sharing in the life sciences. We divide protein sequence information into inflexible data called basic data and data that characterize sequences so called annotation". Based on the definitions cited above and more (Anis Kalboussi et al., 2015b), we conclude that the creation of an annotation is composed of two main parts. (i) The activity, the realization of user objectives (implicit or explicit) as highlight information, request help, to share in case of digital support...etc. based on the document in hand. (ii) The object, which considered as

the result of an activity. Here, it refers to shape\form the user draw to highlight pieces of information i.e., circle, underline, square...etc. and the extra information added by him\her. It worth mentioning that this extra information falls in the same context as the original information and had been added with the goal to enrich not to modify. To this end, we can say that the activity is the creation process of an object on a support\document. In follow, we detail each part:

3. THE ANNOTATION OBJECT

3.1. Object Components

- **Anchor:** The anchor of the annotation can relate to different types of passages, a single word, a line, a paragraph or an entire document. (Azouaou, 2006; Mille, 2005; Veron, 1997) distinguishes several levels of the anchor, where he considers that the annotation is: in the document (on the page, between the pages) or outside the document. We can globally distinguish two types of annotations according to whether their anchor is inside the document or outside: internal annotations and external annotations;
- **Graphical form:** The different forms that annotations take on the document are particularly studied by the authors. (Mille, 2005) makes a very exhaustive review of the different graphic forms identified in the literature. Mille first takes up the categorizations proposed by the other authors and then proposes a more complete ontology of possible annotation act (addition of the text, highlighting, etc).

3.2. Object Structure

Formalizing the annotation object, regardless of the annotation action, amounts to defining the composition of its structure, (i) what it contains, and (ii) the properties that make it possible to identify and describe it i.e., location of an object in the document, objective of the annotation, author, creation date, type...etc. In the literature, there are different models (Denoue, 2000; Kahan & Koivunen, 2001; Veron, 1997; Weibel, 1997) agree on some fundamental properties: such as the author, the date of creation, the semantics (purpose of the annotation) or the content...etc. where the rest of the properties depends on the needs for which these models were designed.

3.3. The Annotation Activity

After studying the annotation object, in this section, we focus on the activity i.e., creation of an annotation object also called “annotation”. This activity consists of placing graphic forms on the document. Authors in (Huart, 1996; Marshall, 1997), studied the relations correspondence (annotation practices) between a set of graphical forms and the objective (semantic) of the annotation. These relations of correspondence are on one side common and shared in a group and which are on the other hand different according to the context of the annotation. The study demonstrated that it is possible to deduce the goal of the annotations from their graphical form in a context given.

3.4. Features of Medical Annotation Systems

Several medical annotation systems have been developed, in recent years, in the context of digital health domain evolution; these systems are created based on several divergent characteristics (comes from the existence of several standards) related to the concept of annotation and the developed system. An annotation system can be developed as plug-in, web application, or local application. The system is used by a practitioner who is a PHC (doctor, nurse, biologist, and radiologist). The annotation activity style on a system is either: automatic, manual, or semi-automatic. As described above, the annotation activity results in an annotation object of type cognitive or computational. Clearly this assemble three main ideas: 1) the system used to create this annotation hence, each system type has its objectives; 2) what composed the annotation itself as explained above and on what had been

created; 3) the creator of the annotation because each PHC has a certain role and access constraints within a particular medical system. Eventually, those characteristics can serve as criteria to classify the medical annotation systems. In follow, we discuss in-depth independently each of these criteria:

3.5. Type of Medical Annotation Object (Cognitive / Computational)

- **Cognitive Annotation Object:** Has a visible visual form on the digital resources (text, image, video, etc.) and created to be used and analyzed by a human agent. In this case, the annotation requires a cognitive and intellectual effort to be interpreted. The cognitive annotations are regarded as additional content that is strongly related to existing content, meaning that they add values to the existing content by providing an additional layer of elucidation and explanation (Cahier & Zacklad, 2004). This type of annotation is integrated into the application that is used essentially by the radiologist, doctors;
- **Computational Annotation Object:** Also known as metadata is intended to be processed and manipulated by software agents. These objects allow users to annotate digital resources like web pages, text files, databases and even for images and videos to facilitate their exploitation by machines. It is used in the field of information retrieval, summarization, document classification, and indexing. This type of annotation is integrated into the applications that are used essentially by biologists in the domain of Bioinformatics.

3.6. The Medical Annotation Activity (Manual, Automatic, Semi-Automatic)

Annotation activity begins with the choice of an anchor and an annotation form, from the annotation software toolbar. Here, each annotation has numerous properties such as author, creation date ...etc. This process ends with the attachment of the annotation to a well-defined target. Based on this process, we can classify the annotative activity as manual, automatic or semi-automatic (Khalil Chehab, Kalboussi, & Kacem, 2020; Anis Kalboussi, Mazhoud, & Kacem, 2016a).

- **Manual:** The process already mentioned will be carried out totally by the user himself, who selects the form of the annotation, the anchor and creates the annotation. This process is like the process of annotation when paper support is available. Clean tools (“Clean tools,” 2018), IOGram (“IOGram,” 2018) and Medip (“Medip,” 2018)are examples of the manual annotation systems;
- **Automatic:** The annotation process is carried out totally by the machine. These annotations are done based on context sensors, pattern recognition techniques...etc. Epvizr (Ma & Meng, 2018), BioR (Kocher et al., 2014) and BioQRator (Kwon, Kim, Shin, & Wilbur, 2013) are examples of automatic annotation systems;
- **Semi-Automatic:** in this case, the process will be done at the start by the user. After a while, the system acquires and understands how the user annotates. In this state, the system suggests annotations automatically, based on an annotation model built with rules under development. At this stage, human intervention remains just to validate or not validate the suggested annotation which in turn helps to refine the annotation rules created at a certain level. When there are no corrections and there is a complete acceptance of the suggested rules, human intervention is no longer considered or needed, and the process becomes totally automated. Medetect (Tian et al., 2013), Flersa (Navarro-Galindo & Samos, 2012) and Bioannote (López-Fernández et al., 2013) are examples of the semi-automatic annotation systems.

4. HEALTHCARE PROFESSIONAL (PRACTITIONER)

It is the annotator that is equipped with an annotation system to use all the functionalities offered by the latter. In our case, the practitioners are healthcare professionals (Doctors, nurses, biologists, and

radiologists). The healthcare cycle is composed of four phases: diagnostic, treatment, advice, follow up and observation. Each practitioner, with a medical annotation system, intervenes in one or many phases according to their role to accomplish a specific task in which annotation is made.

5. TYPE OF ANNOTATION SYSTEM (APPLICATION, PLUG-IN, WEBSITE)

Several annotation systems are created with different architectures and interfaces that permit annotation adding on digital resources. These annotation systems can be classified according to three criteria:

- **Application:** An application is created to annotate the resources already consulted. These applications offer several functionalities as cited below in section 2.3. Several applications exist such as Heideltime (Zell & Strötgen, 2015), Biocat (Zhou, Lamichhane, Sterne, Ye, & Peng, 2013) and Bioannote (López-Fernández et al., 2013);
- **Plug-in:** These are the expansion modules, an external module that is added to a website or software and which makes it possible to provide annotation functionalities to the latter. Several plug-in exist, such as BioR (Kocher et al., 2014), Domeo annotation (Clark, Ciccarese, & Goble, 2014) and Cart (Deghou et al., 2016);
- **Website:** These are specialized websites to annotate consulted resources by registered users on the web. Several websites exist, such as Mammoapplet (Mata, Oliver, Torrent, & Martí, 2012), DSS-meda (Pawel Mrozowski and Andrzej A. Kononowicz, 2006) and 3dmarkup radiologist (Moreira, Hage, Luque, Willrett, & Rubin, 2015).

5.1. Type of Annotated Resource

Annotated resources can be a word document, pdf, image, text, video, HTML, audio, etc. Table 1 presents a comparative study of fifty medical annotation systems seen in the literature study using the 5 criteria already explained. These annotation systems are ranged on the table according to the chronological order of their publication year. Here, some systems can include manual and automatic annotation treatment or more options thus, we added (×) in all the relative box in the table.

5.2. Functionalities of Medical Annotation Systems

The PHC, who is the annotation system user, benefits from the features offered by these systems (Colley, Rantakari, Virtanen, & Häkkilä, 2017). These systems share several features that are dedicated to annotation management, search, etc. Other features are created especially for a need related to the studied resource, practitioners…etc. In the previous section, we provided a unified classification of annotation systems in e-health domain. In this part, we are interested in making a comparison of these annotation systems based on the offered functionalities offered:

- **Annotation Management:** The existing annotation systems can be classified into two categories. The first category links an annotation to an entire document by a URL, in which case the anchor of the annotation is the entire document. In the second category, the system associates the annotation to a specific part in a document and which is identified by two elements: (i) the annotated part and (ii) the URL; in this case the anchor of the annotation is the annotated part. Each medical annotation system studied can manage annotations through at least one of these functionalities:
  - **Creating Annotation:** Can be automatic, manual or semi-automatic however; in the healthcare field, the automatic annotation is more popular;
  - **Modifying Annotation:** With this function, we can modify the anchor, the shape, the annotating content, and the annotated content;

Table 1. Comparative study of the medical annotation systems using 5 criteria

	Name of the medical annotation system		Year	Healthcare professional (Practitioner)	Annotated Resource type	Category of annotation system			Annotation Type		Type of annotation activity		
						Application	Plug-in	Web	Cognitive	Computational	Manual	Automatic	Semi-automatic
1	**RIL-Contour**	(Philbrick et al., 2019)	2019	R	Text	×			×	×	×	×	×
2	**Santo**	("Santo," 2018)	2018	D	Text			×	×			×	
3	**IOGram**	("IOGram," 2018)	2018	D	Image 3D	×			×		×		
4	**Crowdflower**	("Crowdflower," 2018)	2018	R	Image	×			×		×		
5	**Epivizr**	(Ma & Meng, 2018)	2018	B	Document	×			×		×	×	
6	**Medip**	("Medip," 2018)	2018	R	Image	×			×		×		
7	**ODMSummary**	(Storck, Krumm, & Dugas, 2017)	2017	D	HTML			×	×			×	
8	**3dBionote**	(Segura et al., 2017)	2017	B	Image			×		×	×		
9	**Verdant**	(McKain, Hartsock, Wohl, & Kellogg, 2017)	2017	B	Text			×		×		×	
10	**Best slice**	("Best slice," 2017)	2017	R,D	Image			×	×		×		
11	**MicroMD**	("MicroMD," 2017)	2017	R, D	Image	×			×		×		
12	**Med3D**	(Lavrič, Bohak, & Marolt, 2017)	2017	D	Image	×				×	×		
13	**GIDAC**	(Vizza et al., 2017)	2017	R	Image	×			×		×		
14	**Vcf-miner**	(Hart et al., 2016)	2016	B	Text			×		×	×		
15	**Plexo**	("Plexo," 2016)	2016	R	Image		×		×		×		
16	**BioDigital human**	(Qualter et al., 2012)	2016	D	Image 3D	×			×		×		
17	**Leadtools**	("Leadtools," 2016)	2016	R	Image			×	×		×		
18	**SemAnatomy3D**	(I. Banerjee G. Patané & Spagnuolo, 2015)	2015	R	Image	×			×		×	×	
19	**Icare**	(Marrast, Zaraté, & Mayère, 2013)	2015	N	Document	×			×		×		
20	**Cart**	(Deghou et al., 2016)	2015	B	Image		×			×	×		
21	**Heideltime**	(Zell & Strötgen, 2015)	2015	A	Time	×			×		×		
22	**Clamp**	("Clamp," 2015)	2015	D	Text	×			×		×		
23	**Perfectcare**	("Perfectcare," 2015)	2015	D	Document			×	×		×		
24	**Domeo Annotation**	(Clark et al., 2014)	2014	B	HTML		×			×	×	×	×
25	**BioR**	(Kocher et al., 2014)	2014	B	Text		×			×	×	×	
26	**3dmarkup radiologist**	(Moreira et al., 2015)	2014	R	Image			×		×	×		
27	**Vita**	(Roy, Brown, & Shih, 2014)	2014	R	Image, video	×			×		×		
28	**Marky**	(Pérez-Pérez, Glez-Peña, Fdez-Riverola, & Lourenço, 2015)	2014	R	All type	×				×			×
29	**Cliosoft dental**	("Cliosoft dental," 2014)	2014	D	Image			×	×		×		
30	**Medetect**	(Tian et al., 2013)	2013	D	HTML	×				×			×
31	**Bioannote**	(López-Fernández et al., 2013)	2013	B	Image	×				×	×		
32	**Biocat**	(Zhou et al., 2013)	2013	B	Image	×				×		×	
33	**Gate**	(Bontcheva et al., 2013)	2013	A	Text	×			×		×		×
34	**BioQRator**	(Kwon et al., 2013)	2013	A	Text			×	×			×	
35	**Anafora**	(Chen & Styler, 2013)	2013	A	Text		×		×		×	×	
36	**Ratsnake**	(D.K., T., C., & I., 2014)	2012	R	Image		×			×			×
37	**Flersa**	(Navarro-Galindo & Samos, 2012)	2012	R	Image	×			×		×		×
38	**SMItag**	(Federico, Néstor, & Oscar, 2012)	2012	R	Image			×		×	×		
39	**Mammoapplet**	(Mata et al., 2012)	2012	R	Image			×	×		×		
40	**Brat**	(Stenetorp et al., 2012)	2012	A	Text	×			×		×		
41	**Idash**	(Ohno-Machado et al., 2012)	2012	D	Text	×			×		×		
42	**MedAt**	("Medat," 2011)	2011	D	Document	×				×			×
43	**DoctorEye**	(David et al., 2012)	2010	R	Image	×			×		×		×
44	**Radsem**	(Möller, Regel, & Sintek, 2009)	2009	D, N, R	Image, text, video		×			×	×		
45	**@note**	("@note," 2009)	2009	B	text	×				×		×	
46	**Ipad**	(Rubin, Rodriguez, Shah, & Beaulieu, 2008)	2008	R	Image		×			×	×		

continued on following page

Table 1.Continued

	Name of the medical annotation system		Year	Healthcare professional (Practitioner)	Annotated Resource type	Category of annotation system			Annotation Type		Type of annotation activity		
						Application	Plug-in	Web	Cognitive	Computational	Manual	Automatic	Semi-automatic
47	**Arthemis**	(Liu et al., 2007)	2007	R	Video	×			×		×		
48	**DocAnnot**	(Bringay et al., 2004)	2006	D, N	Document	×							×
49	**DSS-meda**	(Pawel Mrozowski and Andrzej A. Kononowicz, 2006)	2006	D	Video			×		×	×		
50	**Annoteimage**	("Annoteimage," 2005)	2005	R	Image	×				×	×		

B: Biologist, D: Doctor, N: Nurse, R: Radiologist, A: all healthcare's professional

  - **Saving Annotation:** Once the annotation is created it must be stored for the purpose of exploiting and reusing them. This function offers the possibility to record this annotation in a form specified by the constructor of the system;
  - **Delete Annotation:** Deleting an annotation without archiving;
  - **Viewing Annotation:** Many systems offer a specific view manner. These viewing methods include an ordering algorithm that offers the prioritization view, Gantt view... etc.;
- **Sharing an Annotation:** Share the annotation with healthcare professionals, this can help health professionals in collaboration;
- **Send a Message:** The PHC sends a document or record that contains annotations. This function assures asynchronous communication between PHC;
- **Filtering Annotations:** See below:
  - **Manual:** The professional healthcare can choose to view only a collection of annotations chosen according to criteria;
  - **Automatic:** The healthcare professional visualizes only the annotations for which he\she has the right to see;
- **Searching Annotation:** Searching an annotation based on several criteria;
- **Fusing Annotated Documents:** Creating a report of annotation with annotated documents. Fusing can offer a summary of the state of a patient based on annotation. Moreover, this function facilitates for paramedic practitioner the preparation of deposit report that is exchanged between paramedic healthcare which contains the state of all hospitalized patients;
- **Comparing Annotation:** This function allows us to compare annotations and decide if these annotations have the same significance or not;
- **Refining Annotation:** The practitioner draws a shape manually of an annotation object. Then, the computer intervenes automatically to re-trace\adjust the shape drawn manually. This function used a lot in medical image annotation;
- **Extracting Annotation:** From an annotated document to be stored in a specific form (text, XML… etc.) or to be analyzed;
- **Linking Annotation to an External Source:** The annotated content is a link to an external source as a document, website...etc.;
- **Localizing Annotation and Area Calculation of Annotated Zone:** This function offers the coordinates of the shape used in the annotation and calculates the area of this shape. The medical image which has already been annotated can be reused with this function that is able to localize the annotation. The annotated zone in the image is an abnormal zone (sick zone) and the calculation of area can offer additional information;

- **Linking Annotations:** This functionality offers the possibility of linking annotations. This link means that these annotations are dependent. Understanding an annotation is done by exploring other annotations related to this annotation;
- **Classifying Annotations:** This feature allows classifying annotations according to a classification parameter specified by the annotation system. The classification provides information that is easily exploited.

Table 2 presents a comparative study of the medical annotation systems seen in the literature review based on the functionalities offered by each system as a criterion for comparison. This technical study helps us in future works at the design of the medical annotation model.

6. LIMITATIONS AND OBSERVATIONS

The study of 50 annotation systems in the field of E-health, with the aim of providing a unified classification criteria and a comparison of the functionalities offered by these systems, allow us to deduce the following limitations and challenges:

6.1. Lack of Liaison Between Resources Consulted and Annotations

Several studies show that doctors use websites (Sophie clément, 2016). In 2010, according to the Center for Studies on Specialized Medical Information Materials, 76% of French generalist doctors used the Internet as part of their professional practice at least once a week (Teston, 2010). In Canada, in a study published in 2013, the interviewees used preferentially medical books or the opinion of a colleague to make a specific clinical decision. For continuing education, websites ranked third with 49% utilization, behind medical journals 93% and clinical practice guidelines 70% (Kosteniuk, Morgan, & D'arcy, 2013). These external resources are consulted following a need for information during the identification and management of a health issue. The analysis of the information, also called the active reading of the information, provided by the patient is a combination of the reading with a certain critical thought, in this context a PHC can annotate the information of this document (Adler & Van Doren, 2014). The annotations can take place on different resources and following these annotations the PHC tries to determine an action that is related to the patient health issue. The automatic link between the resources consulted and the annotations already made within these resources is a phase that is so far not done.

6.2. Annotation is not an Objective

The sharing of the same functionalities, already observed in Section **2.2**, by medical annotation systems shows underuse of the semantics of medical annotative activity. This means that these systems provide the utilities to create an annotation and nothing beyond that. Annotating is not an objective, but it is a means to reach the goal (annotate to recall, annotate to explain, annotate to share, etc.). It can be said that the annotative activity begins with the creation of the annotation and ends with the invocation of the functionalities that can improve, assist and help the professional healthcare as soon as the annotation is created to benefit the most from it.

6.3. Lack of the Specialized Systems of Annotation

A patient record contains several resources (administrative, medical care, medical report...etc.). Each of these resources has a specificity related to several elements among which we quote: type of document, the staff of PHC working on this document. Indeed, these two elements were used as classification criteria in table1. The specificity of each medical document requires the existence of a specific annotation tool, which uses a specific dictionary of word used by this PHC, for each type of document. This study shows that most existing medical annotation systems are developed to annotate

Table 2. Comparative study of the medical annotation systems using the functionalities offered by each system

	Name of Annotation System		Functionality												
			Managing	Sharing	Sending annotated Doc	Filtering	Searching	Fusing	Comparing	Refining	Extracting	Linking to external source	Localizing and calculating annotated zone	Linking annotations	Classifying annotations
1-	**RIL-Contour**	(Philbrick et al., 2019)	×			×	×				×		×		×
2-	**Santo**	("Santo," 2018)	×	×											
3-	**IOGram**	("IOGram," 2018)	×										×		
4-	**Crowdflower**	("Crowdflower," 2018)	×												×
5-	**Epivizr**	(Ma & Meng, 2018)	×												
6-	**Medip**	("Medip," 2018)	×								×		×		×
7-	**ODMSummary**	(Storck et al., 2017)	×						×						
8-	**3dBionote**	(Segura et al., 2017)	×		×		×								
9-	**Verdant**	(McKain et al., 2017)	×												
10-	**Best slice**	("Best slice," 2017)	×	×			×								
11-	**MicroMD**	("MicroMD," 2017)	×												
12-	**Med3D**	(Lavrič et al., 2017)	×							×	×		×		
13-	**GIDAC**	(Vizza et al., 2017)	×								×		×		
14-	**Vcf-miner**	(Hart et al., 2016)	×			×									
15-	**Plexo**	("Plexo," 2016)	×												
16-	**BioDigital human**	(Qualter et al., 2012)	×	×							×	×		×	
17-	**Leadtools**	("Leadtools," 2016)	×										×		
18-	**SemAnatomy3D**	(I. Banerjee G. Patané & Spagnuolo, 2015)	×												
19-	**Icare**	(Marrast et al., 2013)	×			×	×	×							
20-	**Cart**	(Deghou et al., 2016)	×												
21-	**Heideltime**	(Zell & Strötgen, 2015)	×			×	×								
22-	**Clamp**	("Clamp," 2015)	×											×	
23-	**Perfectcare**	("Perfectcare," 2015)	×												
24-	**Domeo Annotation**	(Clark et al., 2014)	×												
25-	**BioR**	(Kocher et al., 2014)	×				×	×			×				
26-	**3dmarkup radiologist**	(Moreira et al., 2015)	×										×		
27-	**Vita**	(Roy et al., 2014)	×								×				
28-	**Marky**	(Pérez-Pérez et al., 2015)	×		×		×								
29-	**Cliosoft dental**	("Cliosoft dental," 2014)	×										×		
30-	**Medetect**	(Tian et al., 2013)	×		×										
31-	**Bioannote**	(López-Fernández et al., 2013)	×		×		×								
32-	**Biocat**	(Zhou et al., 2013)	×												
33-	**Gate**	(Bontcheva et al., 2013)							×						
34-	**BioQRator**	(Kwon et al., 2013)	×												
35-	**Anafora**	(Chen & Styler, 2013)	×					×							
36-	**Ratsnake**	(D.K. et al., 2014)	×							×					
37-	**Flersa**	(Navarro-Galindo & Samos, 2012)	×												
38-	**SMItag**	(Federico et al., 2012)	×												
39-	**Mammoapplet**	(Mata et al., 2012)	×	×			×						×		
40-	**Brat**	(Stenetorp et al., 2012)	×			×	×					×		×	
41-	**IDash**	(Ohno-Machado et al., 2012)	×			×			×					×	×
42-	**MedAt**	("Medat," 2011)	×												
43-	**DoctorEye**	(David et al., 2012)	×												
44-	**Radsem**	(Möller et al., 2009)	×	×								×			

continued on following page

Table 2. Continued

	Name of Annotation System		Functionality												
			Managing	Sharing	Sending annotated Doc	Filtering	Searching	Fusing	Comparing	Refining	Extracting	Linking to external source	Localizing and calculating annotated zone	Linking annotations	Classifying annotations
45-	@note	("@note," 2009)	×		×										
46-	Ipad	(Rubin et al., 2008)	×												
47-	Arthemis	(Liu et al., 2007)	×				×				×				
48-	DocAnnot	(Bringay et al., 2004)	×	×	×	×	×	×							
49-	DSS-meda	(Pawel Mrozowski and Andrzej A. Kononowicz, 2006)	×												
50-	Annoteimage	("Annoteimage," 2005)	×												

biomedical documents, medical imaging, and natural language written in medical documents (Natural Language Processing) to allow the PHC to collaborate with others PHC, while a medical record is composed of several resources that are not fully covered by specific annotation systems.

6.4. Lack of Modeling a Healthcare Cycle

The healthcare cycle consists of 4 phases: diagnosis, treatment, advice, follow-up, and observation. For a treatment, that is phase 2 of the healthcare cycle, a patient may have one or more cycles of treatment that are strongly linked together to help a PHC in the identification and management of a health problem. But what we have seen in these systems that treat the problem of annotation in the electronic health record (Bringay et al., 2004), (Marrast et al., 2013), there is no consideration of this cycle of healthcare. For example, authors in (Bringay et al., 2004) discussed the possibility of collaboration between PHC to avoid lexical disambiguation, using speech acts, they did not propose a healthcare cycle. The collaboration between the PHC should be directed to the implementation of a conceptual model that considers the creation of the healthcare cycle. As a result of the implementation of the healthcare cycle, the annotations are arranged by phases, linked together in the same phase (as the 2 cycles of treatment) or inter-phase, organized in a way that reflects the creative logic of these annotations. This organization can be a step towards setting up a communication platform with existing annotation systems.

6.5. Lack of the Competency Modeling of PHC

The annotation can be created by a PHC who admits a certain competence in his field. The competence of an individual, at the general sense of the term, is its ability to combine and mobilize through resources such the medical knowledge he\she has extra documents...etc. to identify new solutions or to understand more about certain situations. The available annotation systems do not provide the recommended resources to the PHC. This is because those systems do not have the ability to understand the meaning of the information being annotated and do not track how PHC treats the medical record (absence of healthcare cycle). In other words, the system is not intelligent to mimic PHC competency model\behavior. Therefore, modeling PHC competency will eventually help in creating intelligent annotation systems.

6.6. The Problem of Interoperability

We have seen in this study a fragmented image of annotation systems. Each annotation system is developed by a programming language and each of these uses a different medical dictionary to

annotate resources. The negative effect of this image is seen technically by the difficulty of ensuring interoperability between annotation systems in the digital health field. Interoperability is defined by the ability to cooperate and exchange data despite differences in languages, interface, and execution platform (Heubusch, 2006), (Iroju, Soriyan, Gambo, & Olaleke, 2013). The interoperability of medical annotation systems and even medical information systems, which intervene in healthcare, is a major challenge but there are some obstacles that paralyze the application of this notion that has direct positive effects on human health. The Major obstacles to the application of interoperability of medical annotation systems:

- The lack of a computer infrastructure that allows the exchange of healthcare data between the PHC of private sectors and between the PHC of the private sector and public sectors;
- The complexity of the health field contains a multi-practitioner (nurses, radiologists, physicians, biologists, etc.) who work together to provide patient care. The exchange of information between these practitioners must retain the information as it is provided by ensuring the integrity of the information and the security of data exchanged (Bai, Dai, & Li, 2014; Ryan, 2006). An error that comes from the exchange of this information can lead to the death of the patient or privacy issue;
- Several standards that are created (DICOM, ICD, HL7, OpenEHR, etc.) and used in medical annotation systems. This varied use of standards also the non-normalization of abbreviations used by PHCs makes the application of the interoperability difficult. This problem of not standardizing the used abbreviations leads to the problem of incompatible ontologies and terminology dictionaries (Lau & Shakib, 2005).

7. CONCLUSION AND FUTURE WORK

In this paper, we studied annotation systems of the digital health domain available in industrial and research areas in order to propose a unified classification of this kind of system that is omnipresent in hospital information systems. This panoramic view provided is based on the classification of fifty different annotation systems developed in the literature over the past two decades. The presented list of annotation systems is not exhaustive, but it contains the majority of annotation systems encountered in our survey of annotation tools. Even if there are other annotation systems developed in the literature which is not mentioned in this article, it is certain that these systems can be easily integrated into our classification since the categorization technique is based on cross-cutting criteria applicable for any annotation system that is not exist in our proposed list. The proposed organization of annotation tools is built on the basis of five criteria. Moreover, we classified the annotation systems according to the functionalities each one provides. This classification based on criteria, already explained in our study, which are transversal organizational criteria, facilitates the identification of limitations and possible challenges in the area of the medical annotation systems. In future research, we try to use the results of this study to create an annotation ontological model for PHCs and then try to generalize them to be functional for all professionals in different domains. Based on the model we are going to propose an annotation application that overcomes the shortcomings raised by this research. This application will offer a list of services that can assist the PHC based on the semantics of the annotation made by the latter and on intelligent reasoning mechanisms.

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