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Research Article

Annotation Meta-Model for Collaboration among Health Professionals

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Abstract:

Collaboration among Health Professionals (HPs) is a cornerstone of high-quality medical care. Its success depends not only on the availability of clinical information but also on the effectiveness of information exchange. Electronic Health Records (EHRs) have become the central medium for storing and sharing patient data, yet current systems rarely capture the dynamics of professional interactions. This limitation reduces the potential of EHRs to fully support collaborative decision making and coordinated care. To address this gap, we propose an annotation-based approach aimed at enhancing collaboration within EHR environments. Our contribution is threefold. First, we define methods to structure interactions by explicitly capturing who communicates what and when, thereby organizing the flow of exchanged information. Second, we introduce semantic enrichment techniques that add contextual and meaningful interpretation to annotations. Third, we design a meta-annotation model, grounded in a Knowledge-Based System (KBS), that formally represents collaborative exchanges and ensures consistency. A software prototype operationalizes these concepts, providing a practical tool to support annotation creation and management. By bridging raw information with structured, semantically rich collaboration, our approach enhances workflows, strengthens decision-making, and ultimately improves healthcare delivery.

1. Introduction

Collaboration among healthcare professionals (HPs) is a cornerstone of high-quality care, as it enables the sharing of medical information such as notes, diagnostic proposals, alternative solutions, and other forms of clinical knowledge related to patients. However, despite the critical importance of this exchange, HPs still lack appropriate cooperative tools capable of efficiently supporting such collaboration. To design relevant solutions, it is necessary to first study and understand existing practices, particularly the ways HPs leave traces in Electronic Health Records (EHRs) to facilitate asynchronous collaboration [1]. Previous works have highlighted both the difficulties encountered by HPs when working with EHRs and the value of annotations as mechanisms for coordination and mutual understanding [2, 3, 4].

Annotations are increasingly recognized as a key means for communication and coordination, since they enable the explicit recording of exchanges, enrich patient records, and reduce ambiguities. Several studies in the literature emphasize their potential for collaborative work. For instance, Abioui et al. [5] noted that collaborative annotation stands out as the most effective solution for creating rich, consistent, and coherent annotations across various types of documents. Approaches vary from initiating with a single annotation followed by negotiation among annotators to forum like collaborative sessions designed to maximize knowledge exchange. Similarly, in the context of the semantic web, annotation systems such as DINOSYS [6] have demonstrated the value of distributed and platform independent architectures for collaborative learning.

In education, social annotation tools like WASP [7] illustrate how bookmarking, highlighting, and discussion can support collaborative inquiry-based learning, although adoption challenges remain.

The medical field, being highly knowledge-intensive, has also benefited from advances in annotation systems.

Tools such as AWOCATo [19] emphasize flexibility and customizability across multiple domains, while frameworks for medical imaging, such as suggestive annotation for brain tumor images [8], reduce manual effort and enhance data efficiency. Other works have focused on collaborative semantic annotation of multimedia medical documents, such as surgical videos, where annotation is used not only to document but also to create knowledge through iterative observation, negotiation, and concept development phases [9].

These studies confirm that annotation is both a mediator of interaction and a catalyst for knowledge creation in collaborative medical contexts.

More recently, research has moved toward hybrid solutions combining collaborative tooling, semantic modeling, and artificial intelligence. For example, MetaTron provides an advanced biomedical annotation platform integrating intuitive interfaces, assisted annotation, inter-annotator agreement, and RDF export for semantic reuse [12]. Collaborative Semantic Annotation Tooling (CoAT) enhances interinstitutional annotation of clinical data to promote harmonization and interoperability [13]. Ontology-based approaches have also been proposed to formalize annotation practices and ensure their reusability [14].

Furthermore, the emergence of large language models (LLMs) has introduced new opportunities: frameworks such as EHRmonize [15] and ColaCare [16] show how human-AI collaboration can accelerate medical information extraction and enrich EHR modeling. Interoperability remains a critical challenge, with studies such as [20] and [17] emphasizing canonical ontologies, mapping modules, and knowledge graphs as enablers for consistent data exchange across heterogeneous EHR systems.

These developments highlight a clear research trend: the move toward annotation-centered frameworks that combine semantic formalization, interoperability mechanisms, and intelligent assistance. Yet, despite these advances, the collaborative practices of HPs remain complex, often involving tacit knowledge, multidisciplinary perspectives, and highly dynamic contexts that are difficult to formalize. In this light, we propose a novel approach: the Collaborative Medical Annotations (CMA) meta-model, grounded in a knowledge-based meta-meta-model called Y [18], which is component-oriented. CMA structures the collaborative task of HPs, models annotations as problem-solving methods, and anchors them in the medical domain. By doing so, it provides a formal yet flexible foundation for supporting collaboration in EHRs, while ensuring semantic enrichment, reusability, and integration into modern healthcare ecosystems.

The remainder of this paper is organized as follows: Section **The Y Meta Meta Model** introduces the Y meta-meta-model and explains its role in structuring CMA. Section **CMA Meta Model** details the modeling of CMA according to the three axes of Y. Section **Annotation template for HPs** presents **Anapharm**, our prototype implementation that addresses the problem of collaboration between HPs.The following diagram (Fig.1) shows the modeling layers of our approach. Finally, Section Conclusion and future work concludes with the contributions and perspectives of our work.

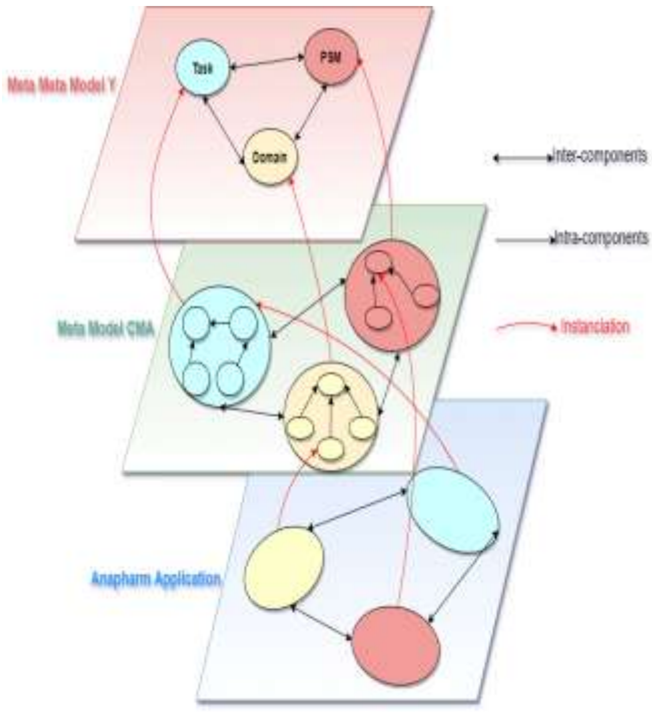

Figure 1. *the three modeling layers of our approach Y-CMA-Anapharm*

2. Approach

Health professionals are used to sticking post-it notes, adding comments as annotations. . . etc. These annotations support some of their daily actions and interactions and actively participate in the collaborative process. Annotation is therefore already an action that allows health professionals to store knowledge, but also to maintain a certain level of coordination and awareness for collaborative work. They are useful not only to store relevant knowledge in the electronic health record, but also help practitioners to collaborate when documents show their limitations. It has been pointed out that collaboration is reduced if this practice is not preserved in the EHR [21]. Therefore, annotations are a relevant support for collaboration between health professionals. Our approach is to solve the problem of collaboration between HPs through these annotations. We have represented it based on KBS knowledge-based systems and using the Y Meta Meta Model.

2.1. The main elements of our approach

A framework for describing a KBS knowledge-based system consists of three main elements: a task definition that defines the problem that should be solved by the KBS; a problem solving method (PSM) that defines the reasoning process of a KBS; and a domain model which describes the knowledge of the KBS domain. Each of these elements is described independently to allow the reuse of task descriptions in different domains, the reuse of PSMs for different tasks and domains, and the reuse of domain knowledge for different tasks and PSMs.
The CMA metamodel supports KBS modeling from reusable components. The separate KBS software components are described in our metamodel architecture :

- **"Collaboration" Task** which defines the problem to be solved by the CMA. The sub-tasks performed by the PSM component are also task components that implement the procedure in order to solve part of the overall problem. Normally, sub-tasks are implemented via an inference engine that executes the rules of the domain knowledge base;
- **PSM "Annotation"** which defines the control structure responsible for the coordination of the subtasks, i.e. the definition of the order in which the subtasks are executed;
- **Domain** that describes the knowledge of the "Medical" field, such as domain rules;

We will then build upon the KBS components, using the Y meta-meta-model as an instance to represent the CMA annotation meta-model, aimed at solving the collaboration challenges among healthcare professionals. we're going to represent this problem using the Y Meta Meta Model [18].
Y is a modeling technique that allows to describe a KBS architecture according to three axes :

- **Components architecture (reuse objects):** this axis allows to see a KBS architecture as a set of interdependent components for reuse purposes. We have identified five concepts in this architecture, three types of components (Task, PSM and Domain) and two types of connectors (Intercomponents connector and Intra-components connector).
- **The levels of granularity of components axis (modeling levels) :** this axis makes it possible to describe the KBS components according to different levels of granularity for the purposes of clarity and reuse. The five concepts already identified in the first axis can be described and refined according to these levels (or layer) which are : meta-ontology, ontology and application.
- **Reuse processes :** this axis also allows KBS components to be viewed as reusable components according to two reuse processes [22]:
  - **"For-reuse"** component-based systems (CBS) engineering : concerns how to build reusable components. The main tasks of this process are : Identify, Represent and Organize.
  - **"By-reuse"** CBS engineering : is about how to reuse an existing component in the component library. The tasks identified for this process are : Find and Select, Adapt and finally Use.

3. The Y Meta Meta Model

In order to reduce application development time and facilitate the maintenance and evolution of this applications, proven techniques are generally used in Component Based Systems (CBS) and Architecture Description Languages (ADL) in particular. These techniques are component-based modelling and meta-modelling. Among these techniques, the Y architecture proposed in our previous work [18].This architecture is a modeling technique that permits to describe a KBS architecture according to the three axes represented previously appearing in (Fig. 2): reuse objects, modeling levels and reuse processes.

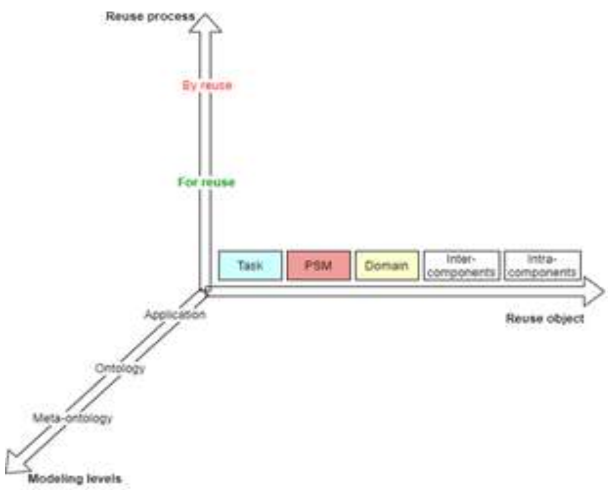

Figure 2. *the three axes of Y architecture*

3.1. The reuse objects axis

The associated modelling process adopted for the Y architecture is based on an extension of the ADL formalism to the multi-abstraction / multi-view decomposition.

According to the first axis, we considers a KBS architecture as a set of interdependent components allowing this type of decomposition. The Y architecture describes the three known concepts Task, PSM, and Domain as three distinct views of a knowledge-based system, similar to the UPML architecture components [23]. It specifies these concepts according to two decompositions, views and abstractions :

- **Views decomposition :** This decomposition is called Separation of Concerns or multiple representation [24]. It makes it possible to define different views of a system that clarify important aspects of it. Such a multi-view decomposition is usually used by human experts to describe complex problems [25]. A view can be assimilated to the vision that a specialist in a domain can have on the system. The number of views is not fixed. It depends on the problem faced and the domain application. The views depend on each other. Thus, two distinct views of a given system can express either complementary aspects or a common aspect, but using different concepts or different levels of description. It is also important to underline the inter-dependencies between the views. The Y multi-view decomposition defines : a task view, a PSM view and a domain view.

Each view is considered as a heavy component in terms of ADL components and is represented in the Y architecture (Fig.3) as a branch so there are three branches:

– **Task branches :** defines the problem to be solved by the KBS and specifies the objectives to be achieved to solve a given problem. Unlike most software engineering approaches, this problem definition remains domain-independent, allowing the reuse of generic problem definitions for different applications. The sub-tasks performed by the PSM component are also task components that implement the procedure in order to solve part of the overall problem. Normally, sub-tasks are implemented via an inference engine that executes the rules of the domain knowledge base.

– **PSM branches :** define the reasoning process of a KBS in domain-independent terms (similar to the inference engine in an expert system [26]. Thus, it defines the control structure responsible for the coordination of the sub-tasks, i.e. the definition of the execution order of the sub-tasks.

– **Domain branches :** describes the knowledge of the KBS domain, such as domain rules; as required by the PSM and task definition.

The inter-component connectors are the interbranch connections (inter-view connectors that allow switching from one view to another) (Fig.3) used to connect components belonging to two different views. Thus, we can navigate from one view to another when building components. For example, when we decompose a task (e.g. T1), we can connect a PSM (e.g. PSM1) to it using a "made-by" connector. The PSM alone can introduce subtasks following the "compound-from" connector.

We have identified three kinds of inter-component connectors :

– **Task / Domain :** These connectors describe the Task / Domain associations. it corresponds to the knowledge roles in the CommonKADS methodology [27], to the task/domain adapter [23] or to the task/domain bridge [28] in UPML.

– **Task / PSM :** These connectors describe the Task / PSM associations. Task and PSM are two concepts that are not often dissociated [27], and when they are, the sub-tasks composing the task are always described either in the composite task body or in the PSM body associated with the task. Thus, subtasks are not considered as tasks and then as first-class components. We can classify here, the work on fixed Task / PSM associations as (role limitation methods) or flexible Task / PSM associations as in the Task methodology [29], Components of expertise [30], the adapters used to link a task with a PSM [31] and Task / PSM mappings in the protegeII methodology [32].

– **PSM / Domain :** These connectors describe the PSM / Domain associations. For example, we can find the work of [33] on PSM / Domain assumptions.

- **Decomposition of abstractions:** It defines different levels of abstraction within a given view. Sometimes, a view is complex enough that it must be described using multiple abstraction levels. Each level introduces specific information, relegating finer details to lower levels of abstraction. The number of abstraction levels depends on the complexity of the view.

The decomposition of a given view is not necessarily isomorphic to the decomposition of other views, although such isomorphism is sometimes imposed in certain models to facilitate verification and validation.

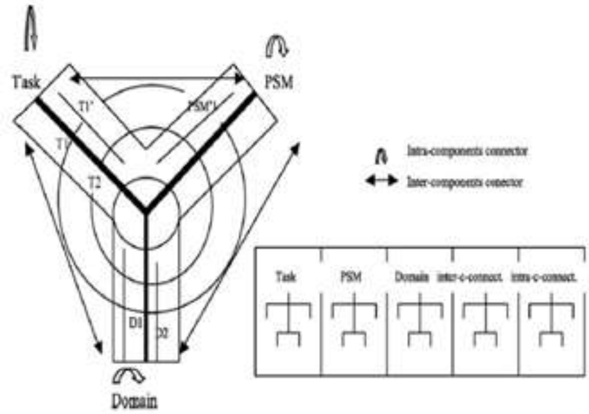

Figure 3. *the Y architecture and the library of components and associated connectors [18]*

In the Y architecture, different kinds of components can exist within the same branch, separated by varying semantic distances**.** This means that each view defining a branch can include several abstraction levels. For example, a task T1 can be further detailed by another task T2**,** which is considered a sub-task of T1. The Y architecture introduces a hierarchical library**.** In Figure 3**,** a circle represents a level of abstraction of a Task, a PSM, or a Domain component. This allows the description of a component belonging to a certain abstraction level at a lower level through an intra-component connector also called inter-abstraction connector which links two components of the same type (Task / Task**,** PSM / PSM, and Domain / Domain). These connectors materialize the semantic distance between two components of the same type. Thus, the greater the distance between a component and the center of the Y, the more reusable the component becomes — but the less directly usable it is. This trade-off is known as the reusability/usability trade-off [34]. The central component of the Y — the intersection of the three branches, where the distances between Task / PSM / Domain are zero — corresponds to a primitive component, where inter-component and intra-component connectors are not required. This central component is essentially a primitive task associated with a primitive PSM containing PSM code, described using the terminology of the associated application domain.

3.2. The modeling levels axis

In this section, we present the hierarchies of the library associated with the Y Meta-Meta-Model, which are structured into three levels of granularity (Fig. 4): the meta-ontological level, the ontological level (library ontology), and the application level. Each level refines and clarifies the previous one by adding more specifications:

- **Meta-ontological Level:**

At this level, the five fundamental concepts of the Y architecture are defined: the three types of components Task, PSM, and Domain and the two types of connectors inter-component connectors and intra-component connectors. The meta-ontological level provides the modeling primitives [35] that serve as the foundation for the architecture. This level essentially represents the Y Meta-Meta-Model itself (Fig. 3).

- **Ontological Level (Library Ontology):**

This level describes the various types of ontologies associated with the three components (Task components, PSM components, and Domain components) as well as the two types of connectors (inter-component and intra-component connectors). These components and connectors are specified using the modeling primitives defined at the meta-ontological level. In our approach, this level represents the CMA Meta-Model, which is an instance of the Y Meta-Meta-Model.

- **Application Level:**

This level is used to describe the applications themselves [36]. In the spirit of reuse, an application is considered as an assembly of three specialized or composed components Task, PSM, and Domain which are interconnected through intra-component connectors and linked via inter-component connectors. These assemblies operationalize the concepts defined at the upper levels, enabling practical implementations of the CMA Meta-Model. This projection of the Y architecture onto the granularity axis levels helps identify the components and connectors at the meta-ontological, ontological, and application levels. These components and connectors populate and define the associated Y hierarchical library.

In the remainder of this paper, we will provide a more detailed description of the components identified along the first axis, that will represent the model for solving the collaboration problem between HPs. These components will be described in depth at the ontological and application levels of the granularity axis.

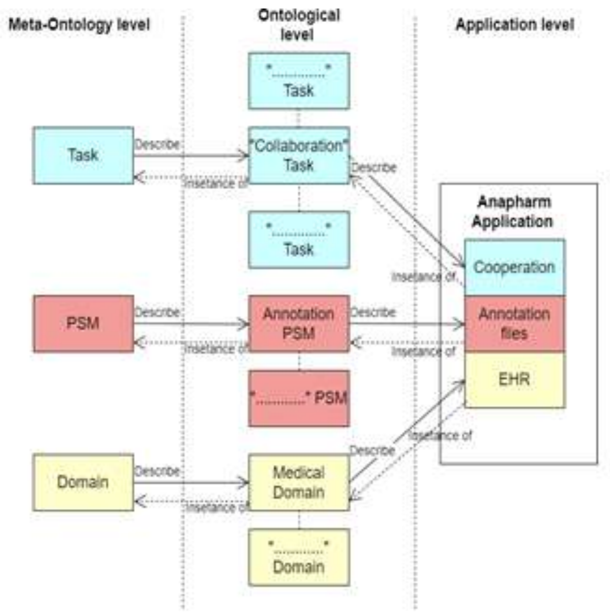

Figure 4. *the hierarchy of the components of the CMA Meta model according to the axis of the modeling levels of the Y Meta Meta model*

3.3. The reuse processes

In the Y architecture, four types of users are involved in carrying out the reuse processes:

- **Infrastructure Builder (IB):** Focused on the meta-ontological level, the IB defines the modeling components used to construct the infrastructure and specifies the meta-ontology elements that constitute the descriptive language.
- **Application Builder (AB):** Concerned with the ontology and application levels, the AB is a domain expert who uses components from the meta-ontology level to describe or specialize components at the ontology and application levels.
- **Reuse Engineer (RE):** Acting as the library manager, the RE builds and manages the library, which consists of two generic parts: (1) generic components at the meta-ontology level (defined by the IB), and (2) reusable components and applications (defined by the AB). Before inserting any component built by the IB or AB into the library, the RE verifies that it is well-documented, thoroughly tested, compliant with standards, and effectively used in applications. This validation step does not apply to already existing components or applications.
- **End User (EU):** Instantiates specific applications to solve real problems by providing the initial values of the problem.

These user roles are defined to separate concerns, facilitate maintenance, and streamline tasks involved in representing the reuse process. This process is divided into two main phases: for-reuse engineering and by-reuse engineering.

For-Reuse Engineering
This phase concerns the construction of reusable components across the three modeling levels : meta-ontology, ontology, and application. The resulting reusable components and applications are then inserted into the library within the layer corresponding to their modeling level. The main tasks in this phase include:

1. **Identifying User Needs:** New components typically emerge from the needs expressed by the AB. This task spans all three modeling levels.

2. **Representing Identified Components:** Components are described using a suitable language, which can be formal, semi-formal, or descriptive. The Y architecture uses modeling primitives defined at the meta-ontology level as a representation language. Due to the flexibility of the Y modeling infrastructure, these primitives can be modified, added, or removed as needed.
3. **Organizing Components:** Once represented, components are checked by the RE and placed into the appropriate level of the library (meta-ontology, ontology, or application).

By-Reuse Engineering
This phase focuses on reusing existing components from the library at the meta-ontology, ontology, or application levels. The main tasks include:

1. **Search and Selection:** These tasks depend on how the library was organized during the for-reuse phase. Searching for and selecting a PSM associated with a given task is straightforward and automatic in the case of a **Task / PSM** organization with a predefined hierarchy (fixed Task / PSM associations). If no such predefined association exists, a search is conducted across the PSM set to identify the most appropriate PSM for the task. As suggested in [18], a PSM can also be used to describe a search algorithm, enhancing flexibility and evolution.

2. **Adaptation:** Adapting a component to a new context can be challenging. In the Y architecture, this is achieved by describing a new component based on an existing one using intra-component and inter-component connectors, following specific predefined adaptation rules.
3. **Use:** Finally, the component is ready for deployment and can be integrated into a new application.

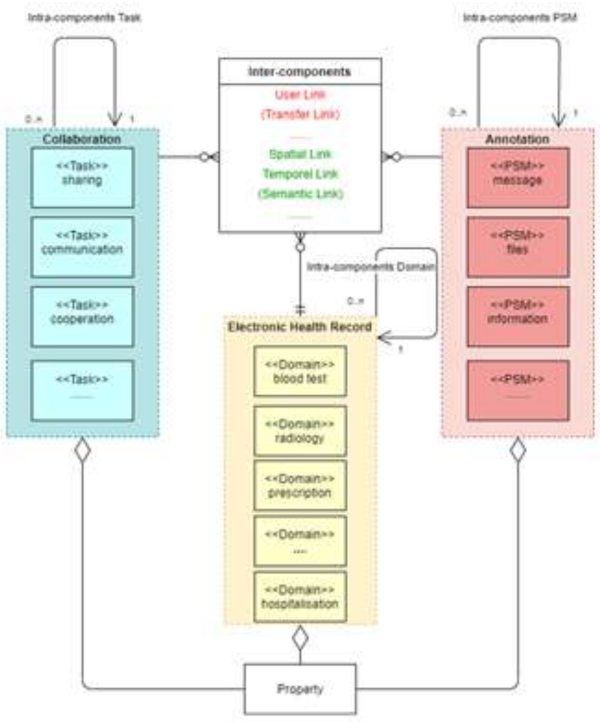

Figure 5. *The Y Meta Meta model*

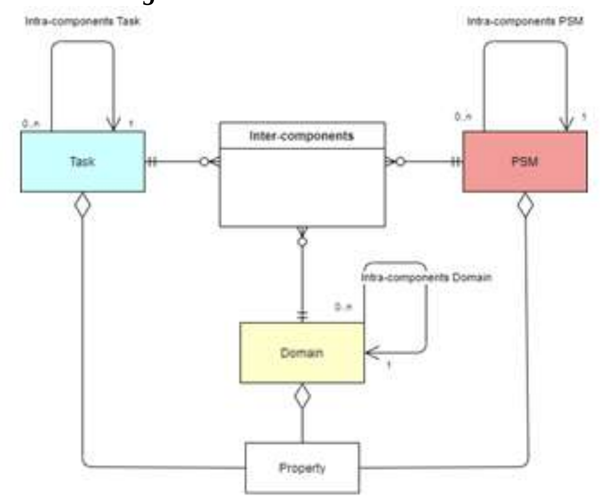

Figure 6. *the components of the CMA Meta model at the ontological level*

4. CMA Meta Model

We build our meta-model based on the Y Meta-Meta-Model (Fig. 5). Several types of ontologies corresponding to all components represented at the meta-ontological level of Y are described at the ontological level. This level specifies the components of the Task, PSM, and Domain, as well as all types of connectors both inter-component and intra-component between them. These five concepts are described using the modeling primitives defined at the meta-ontological level, as presented in [18].

At this level, we represent a Collaborative Medical Annotations (CMA) Meta-Model (Fig. 6), which is an instance of the Y Meta-Meta-Model. The Y model can be viewed as a Y-shaped structure with several branches corresponding to each component:

- **Task Branches:** This branch defines the various types of tasks. Specifically, the set of tasks can be represented as a matrix $〖T〗\_{i,j}$ defined as follows:

$$T = (t_{i,j}) \text{ with } 1 \leq i \leq n, 1 \leq j \leq m \quad (1)$$

A specified task is considered as a column vector of this matrix (a column matrix with n rows and 1 column) where the n rows represent the subtasks of that task:

$$T' = \begin{bmatrix} t'_1 \\ t'_2 \\ \vdots \\ t'_n \end{bmatrix} \quad (2)$$

- **PSM Branches:** These branches describe the various types of Problem-Solving Methods (PSMs). They can similarly be represented as a PSM matrix, illustrating the relationships and variations among different PSM components.
- **Domain Branches:** These branches represent the different domains and their sub-domains. In the medical field, for example, sub-domains include Cardiology, Biochemistry, Dentistry, and others. This branch can also be represented as a column vector within a domain matrix.

In addition to these three branches of the Y architecture, there are two main types of connectors that represent interactions between components:

- **Inter-component connectors:** These connectors represent interactions between two components of different types (belonging to two different branches). There are six types of such connectors: Task / PSM, PSM / Task, PSM / Domain, Domain / PSM, Task / Domain, and Domain / Task.
- **Intra-component connectors:** These connectors represent interactions between two components of the same type (belonging to the same branch). There are three types of such connectors: Task / Task, PSM / PSM, and Domain / Domain.

The Y Meta-Meta Model enables Knowledge-Based System (KBS) components to be treated as reusable components, supporting both reuse processes as described in [22]. By instantiating this reuse concept within our meta-model, we first represent it through the "for-reuse" engineering phase. This phase focuses on constructing reusable components of our model and inserting them into the multi-hierarchical library, specifically within the ontological layer, to facilitate reuse in different contexts. To achieve this, we must first identify the requirements necessary to build the ontological components and connectors for our model. In our case, the problem concerns collaboration among healthcare professionals. Consequently, the Task branch will identify the collaborative work task and its sub-tasks. Identifying the components of this branch requires an understanding of the fundamental concepts of collaborative work. This task must address the collaboration problem and specify the objectives to be achieved to solve it. It should also remain domain-independent to ensure reusability across different contexts. The model-based collaborative task approach demonstrates applicability across a wide range of domains including business and enterprise, education, healthcare, transport systems (e.g., bus or machine tool control), and guideline development. The PSM branch describes annotations, which are considered methods for solving the problem of collaborative work. The third branch represents the medical domain and its various sub-domains. This domain description introduces domain-specific knowledge required by the PSMs (annotations) and the definition of the collaborative task. This knowledge base must include additional constraints and hypotheses that characterize the properties of our domain in this case, the medical domain.

Next, we identify the different types of connectors that link the three branches of our model and represent their interactions (inter-component connectors). As suggested in [23], these connectors act as bridges that integrate the three types of components. In addition, intra-component connectors are identified to link components with their sub-components while maintaining the same type.

Both inter- and intra-component connectors use two types of links [18]:

- **Semantic links:** These define relationships between two components, enabling them to communicate and collaborate through their semantics and behaviors. They can express various associations — logical or physical — such as inheritance, composition, or aggregation. In our meta-model, examples include spatial and temporal links (Fig. 6).

- **Transfer links:** These enable the transfer of data flows between associated components. They apply a transfer function to the source values to derive the destination attributes.

Once the components and connectors are identified, they must be represented using a suitable language. This representation language may be formal, semi-formal, or descriptive. The Y architecture uses the modeling primitives defined at its meta-ontology level as a representation language. As mentioned earlier, the Y modeling infrastructure is flexible — meta-ontology primitives can be added, modified, or removed as necessary. Consequently, our model can be represented as a set of tasks and PSMs using the descriptive primitives of the Y meta-ontology.

Finally, the components and connectors represented in the previous step must be organized within the multi-hierarchical library according to a multi-abstraction / multi-view decomposition, selecting the appropriate level for each and applying a suitable organizational structure. The most commonly used structure for ontological components is a Task / PSM tree, where PSMs are indexed based on their competence, assumptions, functionalities, or problem types. Another organization uses two distinct tree structures: a Task tree and a PSM tree, with the Task / PSM link defined dynamically according to the execution context via connectors.

In the Y library, ontological components are organized into hierarchies based on the user’s choices [18]. After representing our model in the first “for-reuse” engineering phase, we must demonstrate how it can be represented in the second phase, “by-reuse” engineering, to enable the reuse of its components and connectors in other contexts.

In this second phase, the Reuse Engineer (RE), responsible for library organization, searches for and selects appropriate components and connectors as required by the Application Builder (AB), who acts as the domain expert. These tasks depend on how the library was organized during the for-reuse phase. For instance, in a Task / PSM organization with a predefined hierarchy of fixed Task / PSM associations, the PSM associated with a given task can be found easily and automatically. If no predefined Task / PSM connector exists, a search is performed across the PSM set to identify the most appropriate PSM for the task based on the context. This search process can be considered a general PSM, which may describe a search algorithm based on the library’s organization to increase flexibility and evolution [1].

After selecting the components and connectors to be reused, the Application Builder (AB) must adapt them. This adaptation can be achieved by describing a new component derived from an existing one using intra-component and inter-component connectors, according to predefined adaptation rules. Finally, the End User (EU) can utilize these components by integrating them into new applications.

4.1. "Collaboration" Task

Collaboration among healthcare professionals is defined as the sharing of roles and responsibilities between physicians and other healthcare practitioners. It is a key factor in improving the quality of care. Collaboration is distinct from simple collective practice, which has become the predominant form of medical work. It has long been an integral part of daily practice within nursing teams, both in hospitals and in community health centers.

The main contribution of collaboration between professionals is twofold. First, it improves the quality of care by enabling more responsive and patient-centered services. Second, it ensures better adaptation to patients' needs while also addressing the legitimate aspirations of healthcare professionals who seek to evolve their care practices through collaborative approaches.

Within the collaboration task, we identify three main sub-tasks:

- **Communicate:** Communication must be clear, explicit, and unambiguous, aiming for a standardized language that avoids misinterpretation.
- **Coordinate care:** Coordination occurs around the patient's medical care, involving different actors to reduce redundant examinations, minimize drug interactions, and avoid transcription errors.
- **Share patient knowledge:** Knowledge sharing enriches the practice of both medical and paramedical professionals. It also facilitates daily clinical work by providing classification tools that enable rapid information retrieval according to various criteria such as data type (clinical, biological, imaging), chronological order, patient name, age, place of residence, or type of condition.

4.2. Annotation

4.2.1. What is an annotation?

In computer science, annotation is defined as graphic or textual information attached to an electronic document, whether it is mono-media, multimedia, or a web page [6]. This definition concerns the annotation object itself and how it is perceived by both the annotator and the reader. Consequently, the form of an annotation may vary depending on the annotator's purpose and intent.

For example, non-textual annotations can simplify future reading or facilitate access to information, depending on the intended use. Such annotations are often graphical in nature underlining, highlighting, or marking specific elements to create a personalized re-segmentation and reorganization of a document or paragraph [5].

Annotations can also be textual, particularly when the annotator is the author of the resource, an expert, or even a regular user seeking to enrich the document by adding additional information in a well-defined context. In this case, the form of annotation depends on its function [37]:

1. Individual annotations are used to translate a term, provide additional definitions, or rephrase a passage.
2. Collective annotations introduce the notion of sharing and exchange, allowing annotators to ask questions, provide answers, and give feedback through annotations.

The graph in Figure 7 summarizes these concepts.

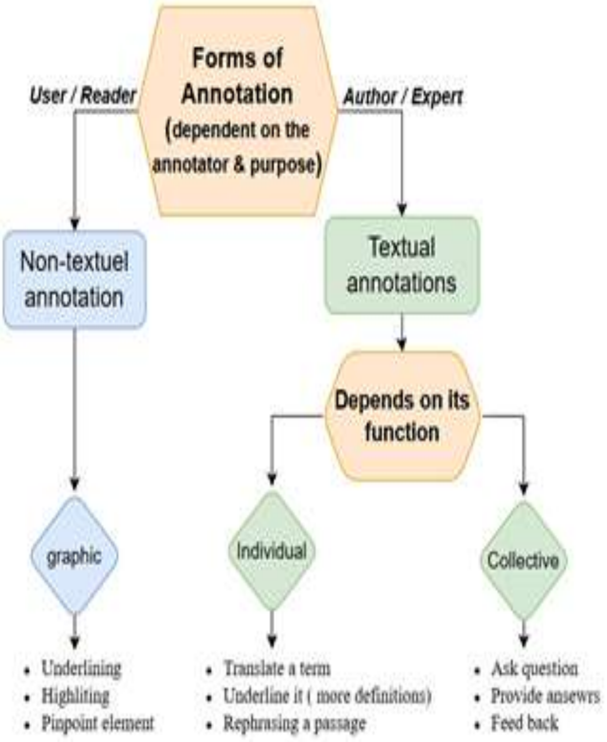

Figure 7. *Annotation forms according to usage requirements*

Based on speech act theory [38], four key dimensions of annotation have been identified [21]:

- **Contextual dimension:** Describes the circumstances that lead the annotator to produce the annotation and those that prompt the reader to consult it. Key questions include: *Who writes?*, *For whom?, Who reads?, About what?, When?*, etc.
- **Perlocutionary (intentional use) dimension:** Describes the annotator's intention regarding the possible and desired use of the annotation, as well as the actual use by the reader. Key questions include: *Why?* and *What are the effects of an annotation on the actions, thoughts, and beliefs of its potential beneficiaries?*
- **Locutionary / illocutionary (communicative) dimension:** Focuses on the linguistic and communicative elements used by the annotator to convey a message and how these are interpreted by the reader. It answers questions such as: *How does the annotator refer to something to express meaning?*
- **Collaborative dimension:** Defines annotation as a literacy strategy that simultaneously engages annotators in critical reading, critical thinking, writing, and collaboration. It describes the impact of annotations on collaborative activities answering the question *What impact?* and highlights the broader collaborative processes that driv

4.2.2. Semantic Annotation

In the context of the Semantic Web, annotation is defined as a relation between two sets of objects [39] :

- $D = \{d\}$: the set of documents d.
- $C = \{c\}$: the set of formal representations c.

This relation defines two functions, where $d \in D$ *and* $c \in C$ [40]:

1. **Annotation function** in the direction $D \rightarrow C$:

$$Annotation(d) = c$$

2. **Index function** in the direction $: C \rightarrow D$

$$Index(c) = d$$

In this context, annotation describes a resource from an objective point of view, in contrast to our medical case, where the annotator a healthcare professional (HP) annotates the EHR of a specific case from a subjective perspective, reflecting their own interpretation and expertise.

The main objective of this work is to enhance cooperation among healthcare professionals (HPs) when accessing Electronic Health Records (EHRs). To achieve this, we propose a semantic annotation service within EHR systems aimed at reducing the risk of misunderstandings among HPs. In this context, word sense disambiguation becomes essential, and this type of annotation is considered highly challenging even for healthcare professionals [41].A vast amount of medical knowledge and patient-related information is archived in EHRs, including medical histories, procedures, prescriptions, diagnoses, clinical examinations, radiology reports, blood test results, and more. These data are provided by multiple specialists with varying levels of expertise and originating from diverse medical fields.The exponential growth of medical knowledge and the heterogeneity of associated information technologies make it increasingly difficult for HPs to access relevant information efficiently. Addressing these challenges requires:

1. A deep understanding of collaboration dynamics among healthcare professionals (*problem space*).
2. An effective exploration of the potential of semantic annotation to support collaborative interactions (*solution space*).

For instance, semantic annotation can allow a physician to quickly access specific information such as a particular result in a blood test table without the need to

manually review the entire document. Furthermore, semantic annotation enables the identification of key medical concepts in clinical texts, which can be used for various purposes, such as highlighting critical patient issues [42].

4.2.3.Annotation as PSMs

In this work, the focus is placed on the collaborative dimension of healthcare professionals (HPs) in their medical practice, without neglecting the other dimensions. As highlighted in the literature, "annotations are not only a way of explaining and enriching a resource with observations, but are also a means of transmitting and sharing ideas to improve collaborative work practices" [43]. For this reason, annotation is considered a method for addressing the collaboration problem, i.e., annotation as a Problem-Solving Method (PSM) of the *collaboration* task. Within this task, three main sub-tasks are distinguished: communication, coordination, and knowledge sharing. Consequently, it becomes necessary to identify the sub-PSMs of annotation that correspond to these three sub-tasks, each contributing to the resolution of collaborative challenges in a complementary way.

5. Annotation template for HPs

Among all healthcare professionals' (HPs) practices, annotations receive special attention, as they are among the most relevant tools for supporting collaboration. Annotations serve as a means of making information persistent, allowing it to be accessed and analyzed later [44]. The objective is to understand why and how HPs annotate paper-based medical records and then to integrate these findings into Electronic Health Records (EHRs).

Two key aspects are central to this issue: coordination and communication among HPs — essential elements of collaborative workflows. This section presents our Collaborative Medical Annotation (CMA) model, which focuses on the precise creation and context-aware storage of information related to medical cases within EHRs.

We define three types of annotations based on their content type:

- **Text:** Users can express opinions or provide information through textual descriptions. Thanks to well-defined object references, users can easily refer to these objects.
- **Multimedia:** This flexible form of annotation allows a wide range of media such as audio recordings, videos, or images to be associated with object references.
- **URL:** This type of annotation enables users to link external content to an object reference through a URL, facilitating the retrieval and display of related information.

Annotation content provides users with a wide range of options to express their opinions, remarks, or proposals, while defining the information associated with the annotated object reference. Basic annotation attributes help capture the original intention of the author and the message conveyed when the annotations are retrieved [44]. These attributes also describe metadata related to the annotation content.To this end, the following elements are stored with each annotation: Spatiotemporal Scene (concept), Annotation Type, Collaborative Session, Tags (or Facets), User, Follow-up, and Domain of Discussion. Table 1 summarizes these attributes.

Table 1. *Collaborative annotation metadata.*

Annotation Attributes	Description	Goal
Spatiotemporal Scene (concept)	Describes the spatio-temporal dimension of the author's current scene, stored with the annotation data	Provides the reader with information about the creative context
Annotation Type	Indicates what the author intended to express	Used for viewing and analyzing annotations; serves as a criterion for grouping annotations, especially for visualization purposes
Collaborative Session	Describes the occasion for creating the annotation (e.g., meeting)	Provides a brief description of the general subject
Tags (or facets)	Assigns arbitrary unstructured keywords to annotations that briefly describe their content; keywords may define a wide range of annotation attributes	Enables searching or filtering of annotation objects
User	Provides information (e.g., ID, name) about the author of the annotation	Allows tracing of annotations created by a specific user or group of users
Follow-up	Defines parent–child relationships (followupAnnotations) introduced by the annotation class	Enables creation of annotation trees, modeling of threads, and extension of the domain scope of subsequent annotations
Domain of Discussion	Specifies the discussion area of an annotation	In the medical case, domains may include Neurology, Cardiology, Emergencies (UMC), General, etc.; this can be used for visualization, filtering, and analysis of annotations by service

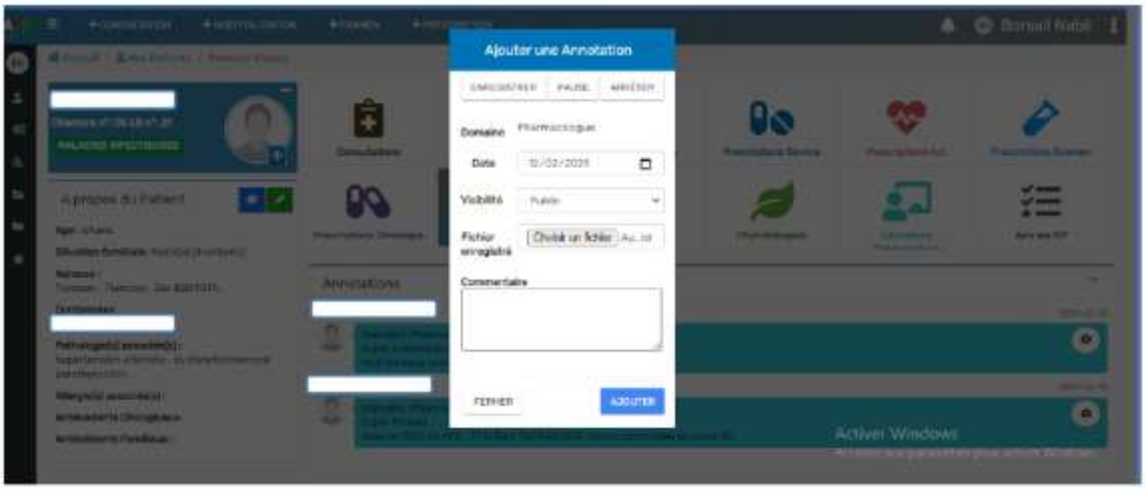

Figure 9. *Annotations of HPs in a given case of HER*

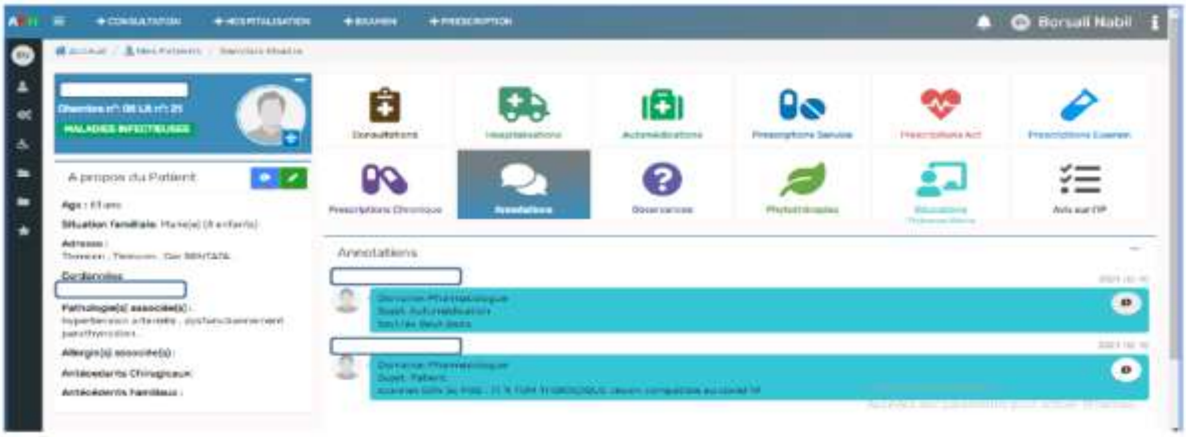

Figure 10: *Adding an annotation to a patient's HER*

5.1. Application Model (Experimental Design)

To validate the proposed approach for collaborative medical annotation, an annotation module was implemented within an existing web-based application called Anapharm, which supports prescription assistance and pharmaceutical analysis [45].Figure 8 illustrates the overall architecture of the application, which is structured around four main modules:

- **Prescription Support Module:** Manages patient records, consultations, and prescriptions.
- **Pharmaceutical Analysis Module:** Closely related to the first module, this component highlights alerts from pharmaceutical analysis based on expert-defined rules and the THERIAQUE database.
- **Administration Module:** Handles user access rights, including account management, profiles, and permissions.
- **Annotation Module:** Enables asynchronous communication among healthcare professionals (HPs) and provides the ability to annotate any part of the EHR while considering spatio-temporal contexts.

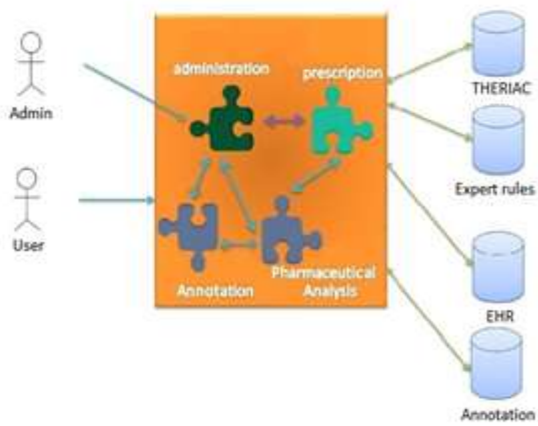

Figure 8. *Anapharm application architecture*

As part of this research, we are currently in the design phase of the annotation module dedicated to EHRs. The decision to integrate annotation functionality directly into the Anapharm application was motivated by the goal of allowing HPs to both create and visualize annotations within their existing workflow.Figures 9 and 10 present screenshots of the main interface of the annotation module in the Anapharm application, illustrating how it supports collaboration among HPs.Following the implementation of the annotation functionality, healthcare professionals were invited to interact with the prototype to validate our hypotheses regarding the usefulness of its features in clinical practice and to gather initial usability recommendations. A feasibility study of the proposed approach was carried out by enabling HPs to manage electronic health records (EHRs) effectively within the system. An evaluation was conducted within the Hematology Department of the University Hospital Center of Tlemcen, involving several healthcare professionals, including pharmacists, physicians, and laboratory technicians. During the COVID-19 pandemic, Anapharm was also deployed in the hospital's COVID-19 unit, where the annotation functionality proved particularly valuable.

HPs reported that the annotation feature significantly enhanced communication and collaboration, especially during periods when physical interactions were limited to reduce direct contact. They also emphasized that the availability of a document annotation layer is highly beneficial, as it provides a non-destructive means of interacting with medical records. This layer enables users to suggest changes without modifying the original content for example, by highlighting important sections, facilitating asynchronous communication, and enhancing the understanding and appropriation of medical records.

6. Conclusion and future work

Medical annotations are highly diverse in both their forms and the functions they perform within the collaborative medical activities carried out by healthcare professionals (HPs) around the Electronic Health Record (EHR). The ontology-based annotation process is structured into two main components: (1) a structured vocabulary or ontology, which is continuously updated and stores annotation terms, and (2) a set of related annotations, which may be created either manually or automatically.

The Collaborative Medical Annotation (CMA) model proposed in this work enables the collection, annotation, and interconnection of information to foster knowledge exchange, collaborative learning, and effective communication among HPs. This model has been formally described and practically demonstrated. The originality of this work lies in its use of annotations as problem-solving methods (PSMs) to facilitate collaboration and communication in clinical contexts. The evaluation conducted with healthcare professionals validates our hypothesis that annotation functionality is indeed useful and valuable in clinical practice. A key advantage of this model is that annotations represented as PSMs are independent of specific domains and tasks, allowing their description and implementation to be reused across different contexts.

Future work will focus on developing a full implementation of this annotation model and exploring its extension to broader applications in digital health.

In addition, particular attention will be paid to the semantic aspects of annotation, notably by clarifying meaning through the use of medical ontologies and by proposing a dedicated collaborative annotation ontology. Further PSMs will also be integrated to enhance the expressiveness and utility of the approach.

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- **Ethical approval:** The conducted research is not related to either human or animal use.
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