Tuberculosis Diagnosis – An Ontology-Driven Conceptual Model

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Abstract

This work applied the SABiO methodology and used UFO foundational ontology to develop an ontology-driven conceptual model in the field of Health Care, focused on Infectious Communicable Diseases for Pulmonary Tuberculosis, called OntoTB. Even today, OntoTB is required, despite existing treatment and being a curable disease, Tuberculosis is one of the 10 main causes of death in the world, demanding a better understanding of the domain to support Information Systems. The model was developed and validated with the support of specialists in Epidemiology. The ontology specification presents the items: graphical representation, dictionary of terms, competence questions and quality control through technical review involving both domain specialists and the competence questions. Among the future possibilities are continuing the expansion of the ontology and developing an automated informational tool to help professionals in the field on data collection and analysis, as well as in decision making.

Keywords

Communicable Infectious Disease, Ontology-Driven Conceptual Model, OntoTB, UFO, SABiO, Health Care, Tuberculosis

1. Introduction

Ontology is multi. It can be used in multiple areas, such as Health and Law. It is developed by multiple areas, such as Computer Science and Information Science. It has multiple definitions – among them, we can quote the definition by Gruber [1], who says that an ontology is a formal and explicit specification of a shared conceptualization. It is classified in multiple ways, such as foundational and domain ontologies. It involves multiple people, such as modelers and experts. It can evolve in multiple ways [2][3]. That's why we decided to work with it.

Work with ontology requires making a choice about a domain. For the present project, it delved into an area of knowledge – **Health Sciences**. It studies fields related to life, health, and disease and that use different methodological principles in the diagnostic, performance, and monitoring phase, that is, in the pre-pathogenesis and pathogenicity of a disease. In this way, there are different research centers in this area and with different study guidelines, so that it can be subdivided into smaller areas.

Health Sciences are a comprehensive and complex domain that studies aspects related to life, health, and disease, and that use different methodological principles in the pre-pathogenesis and pathogenic periods of a disease. In this way, there are different research centers in this field and with different study guidelines, so that it can be subdivided into smaller areas. One of these sub-areas that make up the large area of Health is Public Health, which in turn, is subdivided into smaller areas, including Epidemiology, which studies Infectious Diseases – clinical, epidemiological aspects, mode of transmission and diagnosis through signs, symptoms, and tests, how to fight, what is the treatment and the impact on the infected person's life [4][5][6][7]. This shows the size and complexity of the area, justifying our choice.

OntoCom 2021: 8th International Workshop on Ontologies and Conceptual Modeling, held at JOWO 2021: Episode VII The Bolzano Summer of Knowledge, September 11-18, 2021, Bolzano, Italy
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An infectious disease is a disease resulting from an infection. An infection is caused by the penetration and development of infectious agents such as viruses, bacteria, protozoa, or fungi in the body. These infectious agents can live in a person's body without causing harm or manifesting infection. However, when there is an alteration in the host's immune system, these infectious agents can proliferate and cause a disease [8].

Tuberculosis (TB) is a communicable infectious disease caused by the etiological agent *M. Tuberculosis*, of long duration, which can chance a person's immunity and make it susceptible to other diseases, but which is preventable and curable. It is known that TB can affect several organs and human systems. However, the pulmonary form is the most important for Public Health, as it is responsible for maintaining the disease transmission chain [5][9][10].

Worldwide, TB is the leading cause of death among infectious diseases and one of the 10 leading causes of death overall. In 2019, about 10 million people developed TB and 1.4 million people died, including approximately 208,000 people with HIV [11]. In Brazil, in 2019, there were more than 70 thousand new cases of the disease. Despite having a cure, treatment abandonment is one of the main reasons for Tuberculosis to continue causing fatalities [10][12]. Due to these characteristics, it is believed that the detection, management, and treatment of Tuberculosis can benefit from the use of technological tools, the first step being the development of an ontology to represent the domain.

As the choice of a domain is necessary, the ontology must have a development methodology that adapts to the requirements of the stakeholders. In this sense, we chose to work with the Systematic Approach for Building Ontologies (**SABiO**) [13], which works together with the Unified Foundational Ontology (**UFO**), a foundational ontology, for the development of core and domain ontologies [3]. We named our ontology as **OntoTB** – the Ontology of Tuberculosis. It is a reference ontology that jointly applies SABiO and UFO for the organization of concepts in Health area, focused on Communicable Infectious Diseases and specialized in **Pulmonary Tuberculosis**. The ontology was developed using the Astah UML tool (student version 8.3.0) and uses **OntoUML** as the modeling language.

There are some options available for us to select as a foundation, such as BFO [14], DOLCE [15] and UFO [16]. We chose to work with UFO, as we are already familiar with such a foundation and the tools for building models with such a foundation. In addition, UFO is already successfully applied in different domains, such as Law [17] and Water Quality Data [18], as well as int Health itself [19]. There is also have the curiosity to continue investigating the performance of UFO in the Health domain.

A brief search for related works showed some interesting results, including: (1) OntoSaúde [3] is an overview of an ontology in Health area that applied SABiO approach and was mapped to a data model using the REDCap[2] tool, which resulted in a data collection instrument. From OntoSaúde onwards, studies concerning the domain of TB were started, discussed in [20] and continued in the present paper; (2) Pasini [21] presents a study on the application of ontologies as a solution to organize the existing vocabularies in the field of Health. The proposed ontologies came from a project, OntoData, which studies ontologies in the discovery of knowledge in Health and originated two ontologies: one totally based on the International Statistical Classification of Diseases and Related Health Problems (ICD10) and one that reuses the CID10 ontology and presents the Basic Data Indicators for Health in Brazil (IDB) as principles for its development; (3) Tuberculosis Ontology for Host Systems Biology [22] is an operational ontology that presents a collaborative database with a standardized vocabulary of the main concepts in the domain of Tuberculosis, covering the existing terminology with a clinical focus of the disease. The difference between OntoTB and the one proposed in [22] lies in the organized presentation of the domain concepts and their relationships in a graphical, not just textual, manner. The study of such ontologies showed that there is still space for a proposal such as OntoTB. At the same time, some of these ontologies could have concepts reused by our proposal.

After the introduction, this text is structured in the following sections: Section 2 brings the methodology adopted for the work and a brief theoretical reference on the main concepts that are necessary to understand the text. Section 3 contains the portrait of conceptual modeling created from studies carried out and information acquired during the process (SABiO). Section 4 presents the final considerations, as well as future works.

[2] Research Electronic Data Capture is a web browser-based software that enables the creation and management of databases online.

2. Adopted Methodology and Brief Theoretical Foundation

Ontologies, in general, can be used to describe concepts of a problem domain, allowing knowledge about this domain and it's understanding to be facilitated [23]. They provide uniformity to the concepts, aim to designate an information organization structure with a foundation that is capable of being read and understood by people and machines, can provide the semantic interoperability[3] of data, in addition to representing a reality or domain and its relationships, using specific vocabularies [20][24]. Despite the great benefits that an ontology can bring to Information Systems and Knowledge Management, the understanding of what ontologies are still not widespread as desired.

Complementarily, in Computer Science, conceptual models facilitate communication between their stakeholders, and can be used to provide mechanisms that machines can understand, through modeling for an operational language that can be read and understood by the machine, and to process a given domain and they are an expressive and accurate representation of the domain they aim to represent. One way to obtain the representativeness demanded by these models is using ontologies, giving rise to Ontology-Driven Conceptual Models (ODCM) or simply reference ontologies. Examples of ODCM can be found in the literature, such as the works in [3][23][26].

The ontology development process is dynamic, as it allows for expansion and refinements, to adapt to the requirements of the application environment and its stakeholders. Thus, it is necessary to choose methodologies and technologies that adapt to this process [3][27].

UFO[4], used in the present work, is a high-quality foundational ontology applied in the development of domain ontologies and which provides a basis to support an ontology-driven conceptual model. UFO is organized in 3 layers: UFO-A (of objects), UFO-B (of events) and UFO-C (of social aspects). Furthermore, a strong attraction is having associated a conceptual modeling language, the OntoUML[5], and editors that support the creation, verification, and validation of ontologies [32], based on UFO.

UFO-A, the main foundation of OntoTB, is an ontology of objects that represents types of individuals that last in time and is composed of categories of elements. One of these categories is `Monadic Universal`, which specializes in `Moment Universal` and `Substantial Universal` – both represent categories of individuals. `Substantial Universal` are independent, that is, their existence does not depend on any other individual. The `Moment Universal` is dependent on other individuals [16].

`Substantial Universal` specializes in `Sortal Universal` e `Mixin Universal`. `Sortal Universal` are objects that have the same principle of identity at any point in time. `Mixin Universal` brings together individuals who have common properties and different identity principles [16].

`Sortal Universal` specializes in `AntiRigid Sortal` and `Rigid Sortal`. `AntiRigid` types are concepts that can change over the course of their existence and that are instantiated for a period. These may be specialized in `Role` e `Phase`. `Phase` types are temporary states that an entity can have. In turn, `Rigid` do not change over their lifetime and are instantiated as long as they exist and are specialized in `Substance Sortal` e `Subkind`. The `Substance Sortal` provides identity principles to other instances and is subdivided into `Kind`, `Collective` e `Quantity`. `Kind` type is responsible for providing identity principle to individuals. `Quantity` type is used to represent instances that have a quantitative character [16]. As an example, we can cite Person, which is an instance of type `Kind`; Adult, an instance of type `Phase`; Sample is an example of `Quantity` and as `Role` we can cite Health Professional, a role that Person plays in being related to the area of Health.

As important as choosing the foundation on which the reference ontology will be based, it is necessary to choose the appropriate development methodology. Ontology Engineering is an area that encompasses different methodologies that present techniques and processes for the development of ontologies. The methodology used in the development process of OntoTB was SABiO, proposed by Falbo [13]. SABiO can be applied using UFO as a foundational ontology, being generic enough and

[3] An example of work on can be seen in [25].
[4] For more information on UFO and the constructs, access [16][28][29][30].
[5] It is an expansion of UML profile composed of a set of stereotypes that represent the ontological categories of the universal types of UFO-A and the formal restrictions that reflect the axiomatization of UFO [31].

therefore adaptable to any domain. SABiO was selected because the authors have experience with the process, and it has been applied in successful cases, such as [3][18][26], being a quality methodology.

SABiO is a systematic approach that is composed of five activities in the development process: Requirements Elicitation and Purpose Identification, Ontology Capture and Formalization, Design, Implementation and Test. As well as the main phases, SABiO also includes development support processes, which are: Knowledge Acquisition, Reuse, Documentation, Configuration Management and Evaluation. The activities execution flow is shown in Figure 1.

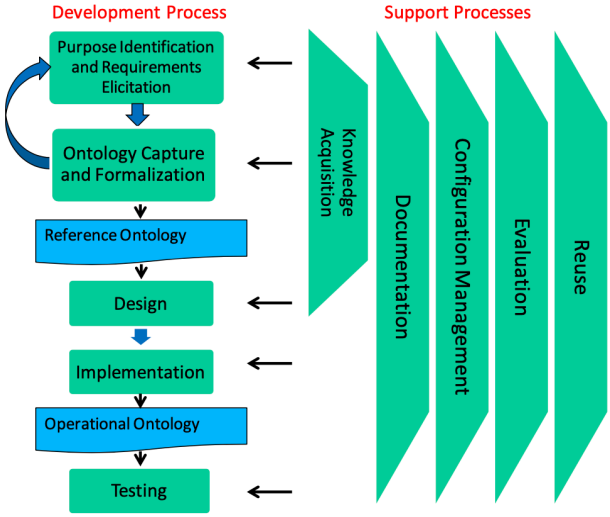

Figure 1: SABiO development process. Source: [13]

OntoTB, a reference ontology, was developed using five SABiO activities: (1) Requirements Elicitation and Identification of Purpose, which consists, through research sources related to the domain and meetings with experts, the study and collection of material about the main concepts of the area so that the purpose of creating the ontology is justified; (2) Capture and Formalization of Ontology, is the construction of ontology; (3) Knowledge Acquisition is a support stage that accompanies the entire ontology construction process, which consists of the study and understanding of the main concepts in the area; (4) Documentation[6], which includes all the results of the development processes, including the purpose, use and competence questions that the ontology, at the end of the process, must answer, the conceptual models and the textual descriptions of the concepts and relationships present in the model, the formal and informal axioms, architecture, design, test cases and results; (5) Evaluation, a process that accompanied the entire development of the ontology. It can be seen from two perspectives: verification, which intends to guarantee the correctness of the ontology construction, according to the specifications defined in previous stages, and validation, which aims to guarantee that the ontology provides all the proposed specifications; and (6) Reuse. The main OntoTB artifacts generated by SABiO activities are described in section 3.

Some SABiO terms connected somehow to OntoTB are: (1) Domain reference ontology, also referred to as an ontology-driven conceptual model, is built with the objective of better describing a specific domain, focusing on the expressiveness of the domain. In this work, the reference ontology is OntoTB itself; (2) Operational ontology is an ontology developed in an implementational language, focusing on computational efficiency; (3) Relational data model is a data model adopted by the relational methodology, being a parallel to the operational ontology. It is one of the future works from OntoTB, as well as item (2); (4) **Competence question** (**CQ**) is a relevant question about the problem domain that must be answered by the developed ontology. An example of a question within OntoTB's competence is: What type(s) of treatment, referring to the health organization, for Tuberculosis is currently present in Brazil? The answer of this CQ it describes in the next section. (5) Derivation axioms enable information to be derived from previous knowledge; (6) Consolidation axioms define the limits for defining an object or declaration of relations. Axioms are complements to the ontology's graphical representation. No axioms for OntoTB have been developed yet.

[6] The glossary of terms is available and can be accessed at https://github.com/ThayzaSacconi/Ontologia-Doencas-Infecciosas

3. Ontology of Infectious Diseases with a Focus on Tuberculosis – OntoTB

During the SABiO requirements elicitation and purpose identification activity, the purpose and use of OntoTB were defined, as well as some competency questions that are pertinent to the domain and that are answered in the end of the process.

The purpose of OntoTB is to present entities, relationships, attributes, and restrictions in the field of Tuberculosis, identified from studies in Epidemiology and interviews with experts in the field. The ontology characterizes a person's relationships with their possible health problems, in this case, Pulmonary Tuberculosis, and the means to diagnose and treat the disease.

The use of OntoTB will provide, to the parties involved, a better way to disseminate knowledge, reducing the difficulty or failure in understanding the subject and allows the generation of an informational tool, such as a data collection instrument for analysis using REDCap, which has been widely used by health professionals, for use by those involved in the domain.

Some of the CQ that must be answered by the ontology are presented in Table 1. The questions were developed from the main questions that health professionals receive from Tuberculosis patients and from those interested in the domain, as identified in the constant discussion with experts. Such questions are the most frequent doubts with by ontology, although they are not the only ones.

Table 1
Examples of OntoTB Competence Questions

Identifier	Subontology	Competence Questions
CQ1	Health Problem	What types of health problems can a person suffer?
CQ2	Health Problem	What types of prevention are present in the current Public Health System in Brazil?
CQ3	Health Problem	What characterizes a communicable disease?
CQ4	Diagnosis of TB	What is the Tuberculosis diagnosis process?
CQ5	Diagnosis of TB	What possible tests can be done to help confirm or refute a case of Tuberculosis?
CQ6	Diagnosis of TB	What possible rankings might a result have?
CQ7	Treatment of TB	What(s) type(s) of treatment, referring to the Health Organization, for Tuberculosis currently present in Brazil?
CQ8	Treatment of TB	What are the possible outcomes of a treatment for a patient?
CQ9	Treatment of TB	Who applies the directly observed treatment?

In the second stage of SABiO, capture and formalize the ontology, the conceptual modeling itself was performed, which aims to represent a fragment of the domain of Epidemiology, which studies Infectious Diseases.

Figure 2 shows OntoTB organized by its subontologies identified in the work context, which are described in Table 2. The subontologies are strongly linked, as the associations between them represent the use of concepts from other modules. The model is divided into the following modules[7]: Person, Health Problem, Epidemiology, Tuberculosis, Diagnosis and Treatment, which considers both the most common treatment and resistant TB[8]. The Epidemiology subontology encompasses general concepts about the natural history of the disease, just as Tuberculosis includes the Epidemiological and Clinical part of the disease[9]. In this work, the following subontologies are detailed: Tuberculosis diagnosis and treatment process. Both based on the Brazilian Health System.

[7] The model is divided into modules and separated by colors to identify the origin of the concepts. The color of each module is identified in Figure 2.
[8] Not included in this work as it is still in the development stage.
[9] The Epidemiology and Clinical Tuberculosis subontologies were published in [20] and can be accessed at http://ceur-ws.org/Vol-2728/short5.pdf

About reuse, concepts were reused in different modules. As an example, we can mention: (1) in the Health Problem module, the reuse was partial of the concepts present in OntoSaúde [3] with some adjustments and insertion of new concepts to contemplate the current study on Tuberculosis; (2) in the Diagnosis and Treatment modules, some concepts were reused from Tuberculosis Ontology for Host Systems Biology [22] and suitable for a reference ontology of Pulmonary Tuberculosis.

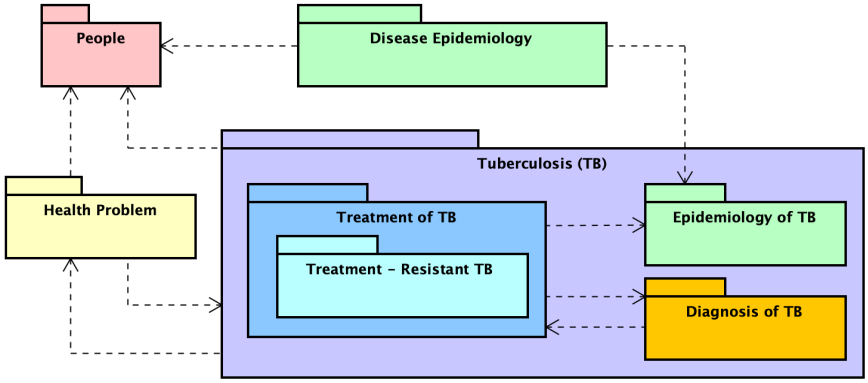

Figure 2: OntoTB Architecture

Table 2
OntoTB Subontologies

Subontology	Description
Diagnosis of TB	It identifies entities and relationships of the diagnosis process from patient signs and symptoms and tests performed by him/her.
Disease – Tuberculosis	Identify entities and relationships of the clinical Tuberculosis disease.
Epidemiology of TB	It identifies entities and relationships of the Tuberculosis disease through fragments of the natural history of communicable diseases.
People	Identifies entities and relationships that describe a Person.
Health Problem	Identifies entities and relationships that describe an overview of health, with stakeholders (Person) and related parties (Diagnosis, Disease and Treatment).
Treatment of TB	It identifies entities and relationships of the most used process of Tuberculosis Treatment, without considering resistance to anti-TB drugs.
Treatment – Resistant TB	It identifies entities and relationships of the TB treatment process used, considering resistance to anti-TB drugs.

Figure 3 presents the Health Problem subontology. Its main concepts are Person and Health Problem, which are related because a Health Problem can affect a Person, turning him/her a Person with a Health Problem. A Health Problem can be an aggravation, or a disease and it is identified through a diagnosis.

A Diagnosis can be Clinical or Epidemiological, the difference between them are the actions of each one's approaches and their objectives. A Clinical Diagnosis aims to cure and prevent the disease in an individual and has Treatment as its main action. The diagnosis will guide a Treatment that will be applied by a Health Professional and offered by a Health Service[10], which in turn can also offer Prevention measures that reduce or avoid the impacts of a disease. As for the Treatment system, it can be classified as Public or Private, depending on its payment method.

At first, we visualized Treatment as a concept that relates the Person With Health Problem, the Health Professional, the Health Problem and the Health Service. However, this is an even more complex

[10] The Health Services studied and presented in this work refer to Public Health System Services in Brazil.

concept than a relationship, needing to be specialized in Treatment Public and Private and Pharmacological and Non-Pharmacological. Because of these specializations, investigating UFO 2.0, we realized that more than `Relator`, this concept fit into `RelatorKind`[11].

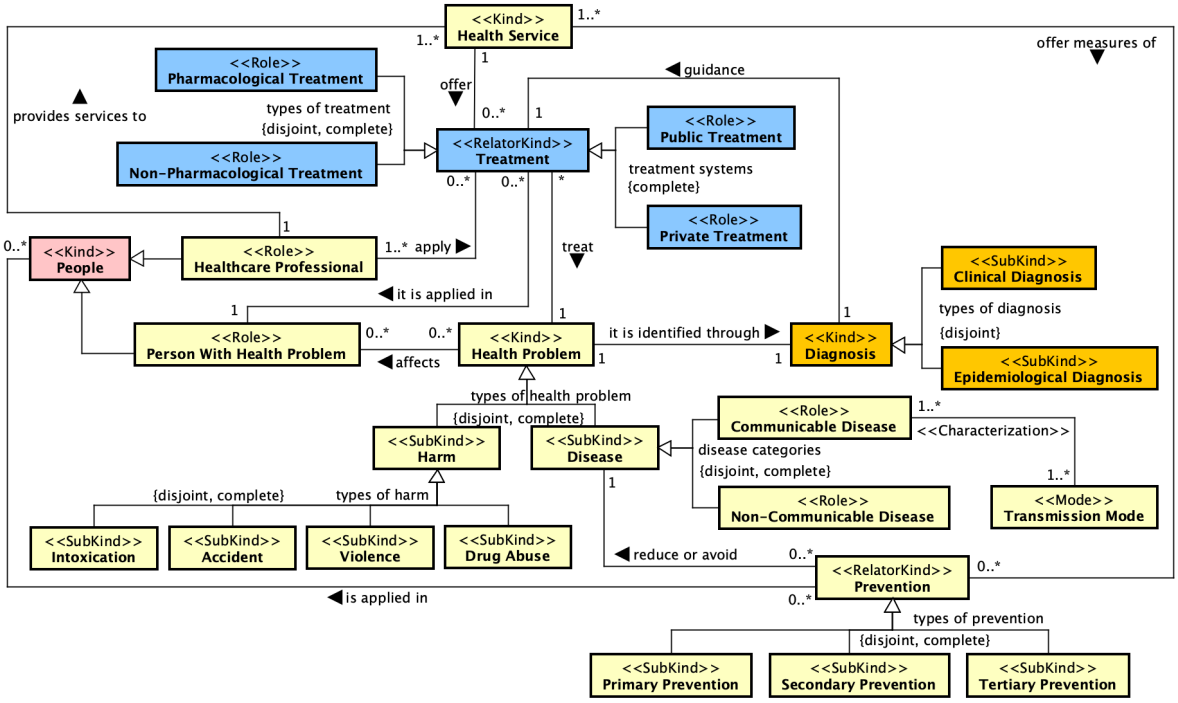

Figure 3: OntoTB – Health Problem Subontology[12]

Diagnosis of TB, the main concept in Figure 4, is made through exams and analysis of the result of a given exam. The Exam has a Result. The Conclusive Result helps in the diagnosis, which in turn has types. These types are related to the Exams performed by the Person with Health Problem, which are: Clinical Diagnoses, or those related to the collective and health promotion; Epidemiological Diagnoses; or special diagnoses related to other diseases that may be TB comorbidities.

Special diagnoses are necessary when we know that TB is the leading cause of death among people living with HIV (PLHIV) who do not undergo the treatment properly. Therefore, when a PLHIV is identified, it is necessary to perform a test for TB and, on the other hand, when a person is diagnosed with TB, it is necessary to take the Rapid Test for HIV.

A Person with Health Problem may be a Respiratory Symptomatic or may be a Clinically Suspected. A Clinically Suspected Person is one who has the presence of a clinical picture compatible with TB but not completely, or who can identify some risk factors that indicate suspicion of TB or other similar diseases. In this case, before diagnosing the disease, it is necessary to carry out one or more exams to assess and conclude the suspicion or discard it. The Respiratory Symptomatic is one that presents all or part of the characteristic signs and symptoms of TB, such as dry or productive cough, with purulent or mucoid expectoration, with or without blood in the secretions for more than 3 weeks. In these situations, or when the diagnosis is confirmed, the Treatment will be started along with the completion of the Compulsory Notification, which notifies a case of illness to the Public Health System. Case information regarding the disease will assist in directing the patient's Treatment Scheme, in addition to carrying out Exams, so that the diagnosis fits the Treatment of the Patient.

The concept that was much discussed was Notification. At first to understand its own meaning in the field of Health. Once we understood the concept, we tried to fit it into a UFO stereotype. First, we classify it as `Kind`, then as `SubKind`. We reached a consensus that this concept is better interpreted as `Role`, as there is the compulsory act of making the notification, a concept that isn't presented

[11] Due to space restrictions in the text, only the main concepts and their respective constructs were detailed.

[12] Concerning some `role` stereotypes present in the diagram of Figure 3. To reduce noise in the visualization of the diagram, the concepts that are associated with the representation of a complete set of `Role`, `Relator` and their relations, are hidden, highlighting the most important concepts of this set to the domain under study.

graphically. The `Relator` Compulsory Notify Reporter is hidden to avoid visual overload on the diagram.

An Exam is the result of an action, which is to examine. The Exam can be classified between Baseline Exams, which are those essential to achieve a Conclusive Result and formulate a Diagnosis of the disease explored, or Auxiliary Exams, also known as complementary, which are those that help the Health Professional to confirm or refute any Clinical Suspicion of a Person with a Health Problem.

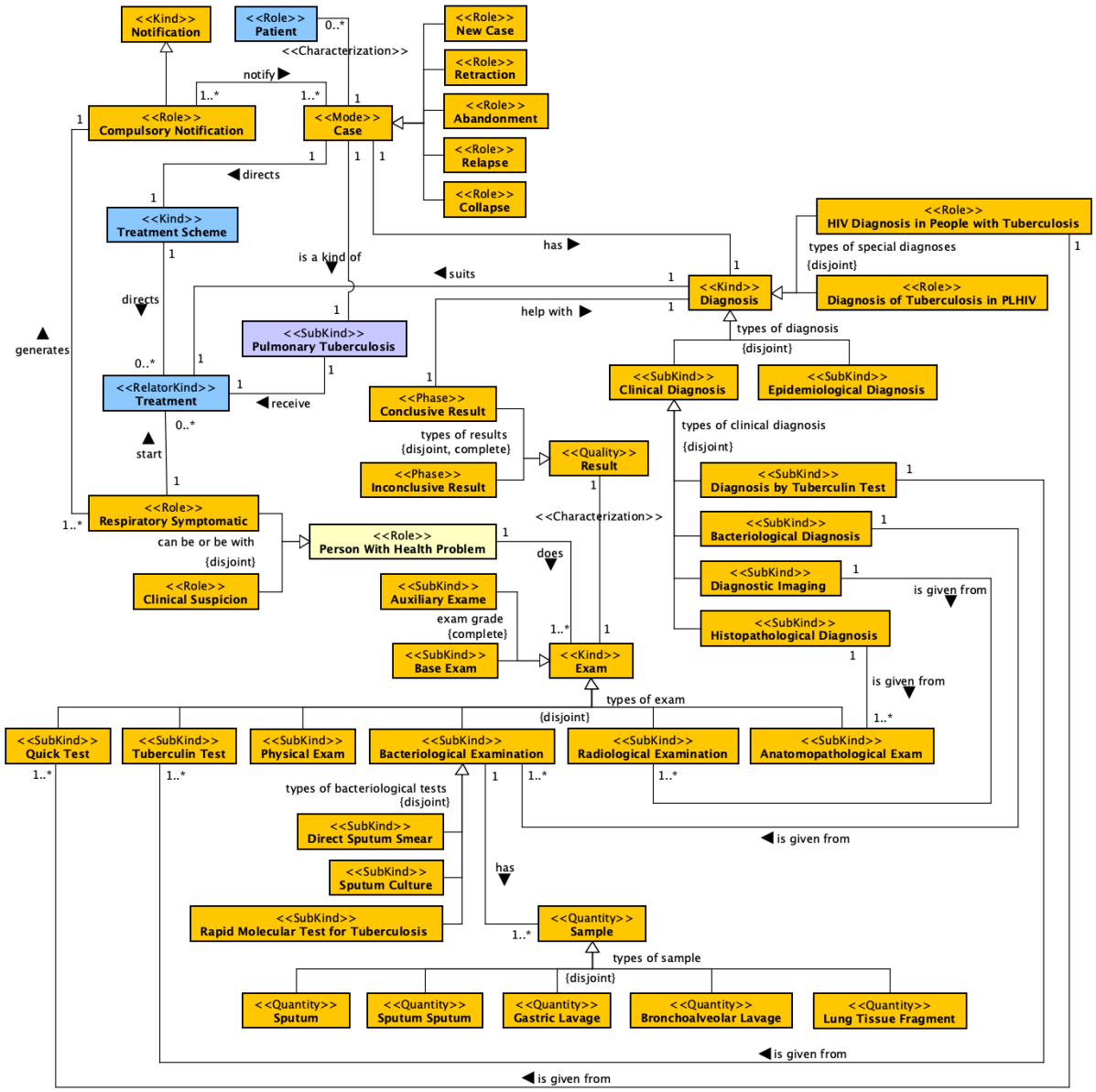

Figure 4: OntoTB – Tuberculosis Diagnosis Subontology[13]

The Exam, in addition to the classification, has types[14]. The Anatomopathological Exam is used to aid in Histopathological Diagnoses and is like a biopsy to identify *M. Tuberculosis* or some other granulomatous inflammatory process that is compatible with TB. This method is used in the investigation of pulmonary forms that present as diffuse disease and extrapulmonary forms. The Physical Examination allows the identification of classic signs of the disease, such as weight loss. The Tuberculin Test is an essential test to know if an individual has had contact with TB bacteria. However,

[13] Concerning some `role` stereotypes present in the diagram of Figure 4. To reduce noise in the visualization of the diagram, the concepts that are associated with the representation of a complete set of `Role`, `Relator` and their relations, are hidden, highlighting the most important concepts of this set to the domain under study.

[14] The types of exams explored here are the most performed, whether essential or complementary, in people seeking to diagnose Tuberculosis.

it is mostly used to diagnose Tuberculosis in its Latent phase, also known as LTBI – Latent Tuberculosis Infection. The Rapid Test is a very common test in TB patients to detect concomitant cases of HIV. The Radiological Examination, an examination that can sometimes be considered an Auxiliary Examination in the Imaging Diagnosis of TB, encompasses the chest X-ray, which should be requested in every patient with Clinically Suspected Pulmonary TB, and the chest computed tomography, which demonstrates anatomical alterations of the affected organs or tissues, being indicated in the suspicion of pulmonary TB, when the initial radiography is normal. The Bacteriological Examination, main in the detection of active TB cases, which performs the collection of Samples, being the most used forms, the sputum, and the expectoration by sputum. These Samples are used in Bacilloscopic and Sputum Culture Examinations to provide a complete Bacteriological Diagnosis. Importantly, patients with a positive Sputum Bacteriological Test support the TB transmission chain. Its Conclusive Result confirms active TB in people with Clinical Suspect for TB and in Respiratory Symptomatic, identified through the active search. The Rapid Molecular Test for TB, also known as TRM-TB, can detect dead or non-viable bacilli. Therefore, they should not be used for Diagnosis in cases of Retreatment, either by re-entry after Abandonment or by Recurrence.

TB can affect any person. However, particularly people with AIDS, advanced stage of HIV Infection, may qualify as a Special Condition that a patient may present upon adherence or even during treatment. Health professionals warn that the concomitant treatment of TB and HIV infection is contraindicated, as there is a possibility of increased intolerance and Adverse Reactions to Drugs, as illustrated in Figure 5, worsening the patient's adherence to the treatment, or causing Treatment Failure.

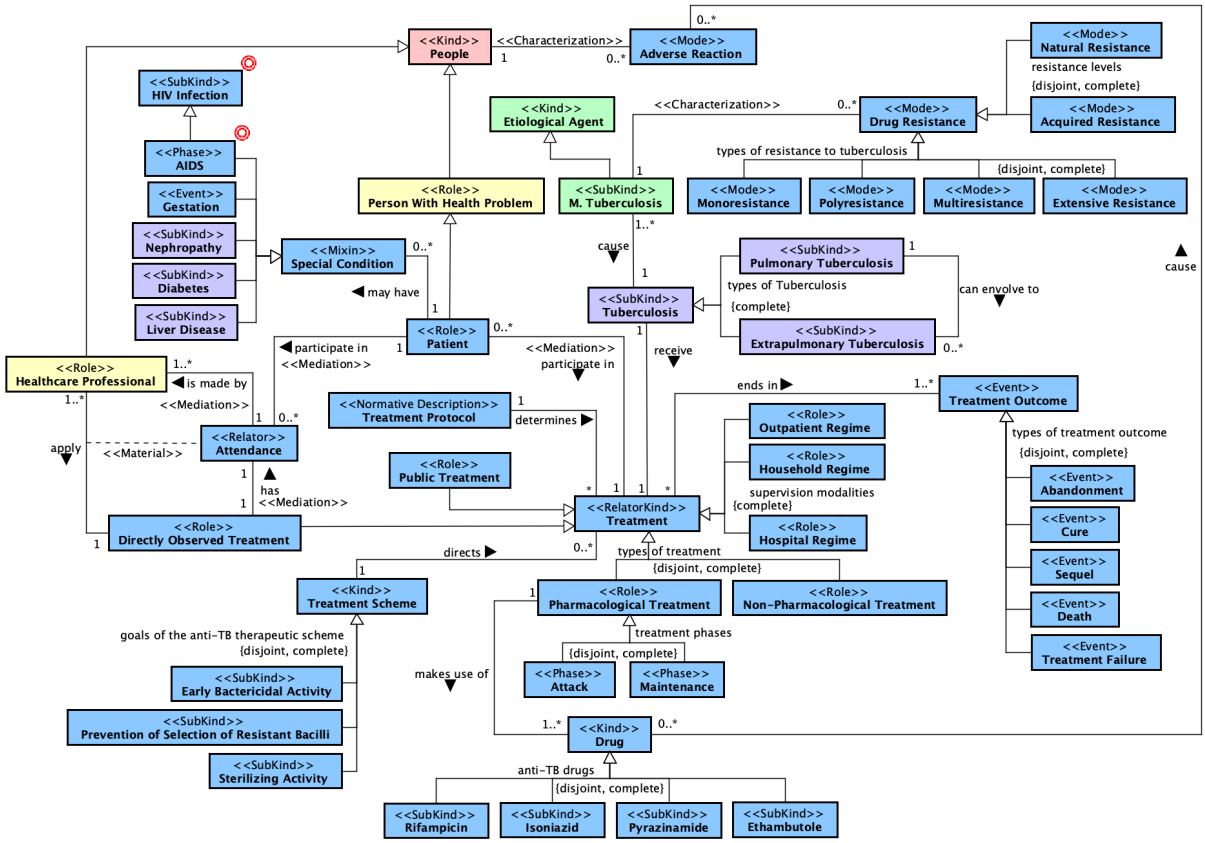

Figure 5: OntoTB – Tuberculosis Treatment Subontology[15],[16]

We realize that a Person With Health Problem, in this case TB, may have some special situations that aggravate the manifestation of TB, such as another disease or gestation. These special conditions

[15] Concerning some `role` stereotypes present in the diagram of Figure 5. To reduce noise in the visualization of the diagram, the concepts that are associated with the representation of a complete set of `Role`, `Relator` and their relations, are hidden, highlighting the most important concepts of this set to the domain under study.

[16] The red symbol that appears in the diagram is to signal concepts that come from other work in development and that will later be associated with OntoTB.

had different UFO classifications because they are different situations. Thus, we had difficulty finding what was common between them until we studied the concept of `Mixin`, managing to fit the term Special Condition in the `Mixin` construct, finding what is common between these different concepts.

We need to highlight that in the treatment of TB, in Brazil, only the Public Treatment is adopted. As for the type, the Treatment can be classified as Non-Pharmacological and Pharmacological. The Non-Pharmacological Treatment in TB is an aid to the Pharmacological Treatment, because, among other factors, it makes possible to reduce the anxiety of the diagnosis in the patient. In Pharmacological Treatment, the use of Drugs is made – the most used drugs are Rifampicin, Isoniazid, Pyrazinamide and Ethambutol. These drugs are given in different combinations and dosages depending on the treatment phase: Attack or Maintenance.

Every Treatment has a Protocol to be followed and a Scheme adopted. The TB Pharmacological Treatment Scheme, to be more effective, aims to have sterilizing activity, to have early bactericidal activity and to prevent the emergence of resistant bacilli. The resistance of *M. Tuberculosis* to drugs can be a Natural Resistance of the individual's body or an Acquired Resistance, which can come from a previous unsuccessful treatment or from discontinuation.

Treatment has different regimens, namely: Outpatient, Home and, in more serious cases, Hospital. There is a classification in parallel to these, the Directly Observed Treatment (DOT), which can be performed both in an Outpatient Regime and in a Domiciliary Regime. DOT is applied by Health Professionals who closely monitor the entire Treatment, aiming at the correct use of drugs and the success of the Treatment (Cure), seeking to avoid patient abandonment.

Last but not least, quality control was a worry of SABiO process, and so, it was considered in OntoTB construction. A technical review was applied, considering verification and validation aspects. This was done by the technical researchers. At this moment, competency questions (as the one identified in Table 1) was observed and their answers were sought in the ontology. Also, an extensive validation phase was executed, and OntoTB was debated by the technical people and the Health experts. The result was a more refined version of OntoTB, prepared for the next steps of SABiO.

4. Final Considerations and Future Work

Other areas, in addition to Computer Science, have benefited from the use of ontologies, both for standardizing concepts related to application domains, and for developing computational tools that help in more accurate analysis based on the large volume of available data, as well as in aiding decision-making. Thus, the present work proposed the application of SABiO for the continuation of the construction of OntoTB, a reference ontology of Pulmonary Tuberculosis, at first visualized in [20]. An initial quality control in conjunction with domain experts showed that OntoTB is a promising ontology, as well as its possible applications. Its competency questions have been answered throughout the descriptions in this text.

Initially, OntoTB addressed more generic concepts of the domain, dealing with Epidemiology and Clinic of diseases, then focused on aspects of Tuberculosis. The result can be found in the work described in [20]. For such generated artifact, research was carried out in the literature and constant contact with specialists in the field, so that the chosen domain was understood correctly. We believe that this way it is a better reflection of the reality.

OntoTB was developed from OntoSaúde [3]. OntoSaúde presents an overview of the basic concepts of Health Problems, which are explored and expanded to include concepts of Communicable Infectious Diseases and further relating them to Pulmonary TB.

OntoTB is expected to explore other Tuberculosis themes, such as Resistant Tuberculosis, Latent Tuberculosis and Extrapulmonary Tuberculosis. The intention is to cover all the concepts of the theme in a more specific way, in addition to presenting the social part of Public Health, such as care, reception and treatment follow-up. This is necessary, as Tuberculosis is a social disease that is related to the housing, sanitation, and education sectors, in addition to Health. It is also intended to expand into different disease domains, as the proposed ontology allows this step, as well as the construction of an automated informational tool, using, for example, the REDCap platform, as seen in OntoSaúde proposal [3]. In addition, the aim is to intensify the use of support processes proposed in the SABiO methodology, such as evaluation and reuse.

The development of OntoTB was an intense learning process. And this learning went through some difficulties, caused by mainly the complexity of the domain, such as the definition of terminology in Health and the choice of the viewpoint that would be adopted. However, it was a worthwhile process, as we believe that OntoTB is a tool for communication and understanding among those involved in the diagnosis and treatment of Tuberculosis.

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