Short Communication

An ontology-based system for chronic tropical diseases using the Protégé-OWL tool

Segun Olatinwo[1,*], Justice Emuoyibofarhe[1], Femi Alamu[2],
Olusegun Omitola[1], and Damilola Olatinwo[3]

*[1] Department of Computer Science and Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria*

*[2] Department of Computer Sciences,
University of Lagos, Akoka, Nigeria*

*[3] Department of Computer Science,
University of Ilorin, Ilorin, Nigeria*

Abstract

This paper presents the development of an ontology for chronic tropical diseases (CTD). As observed in most studies conducted on CTD domain knowledge, the existing ontologies on CTD do not provide a unified structural model for understanding and sharing this domain knowledge which has made it difficult for medical experts to share a common understanding of this domain. This necessitated the need for an ontology-based system to address the challenges. The research data used in this study were obtained from CTD domain experts. Using formal concept analysis, the acquired knowledge was analyzed to obtain the taxonomy entities of CTD. The obtained entities were used to develop the Ontology of Indigenous Chronic Tropical Diseases (OICTD) through the Protégé tool. The developed OICTD was evaluated and compared with the existing Ontology for Tropical Diseases Management (OTDM) using precision, recall and F-measure as performance metrics. The analysis of the acquired knowledge yielded the ontology entities of 936 axioms, 12 classes, 713 logical axioms, 29 object properties, and 182 individuals. The developed OICTD showed a better performance with 97% average precision, 100% average recall, and 98% average F-measure in comparison with the existing OTDM which assumed 78% average precision, 83% average recall, and 80% average F-measure.

Keywords: ontology, formal concept analysis, METHONTOLOGY, precision, recall and F-measure

1. Introduction

Ontology is a way of representing knowledge. Ontology has evolved over time and has brought great opportunities in the way knowledge is being represented in knowledge management and sharing. The sporadic influx of information and communication technology in healthcare has paved the way for the development of a general platform for knowledge sharing and reuse. The management and treatment of most prevalent and indigenous chronic tropical diseases have posed a serious challenge to physicians due to the unavailability and nonuniformity of a generalized understanding of the domain knowledge (Hadzic *et al.,* 2005). More often than not, as observed in most existing studies conducted on chronic tropical disease domain knowledge, it is very difficult to separate domain knowledge from the operational knowledge which accounted for the wrong diagnosis of various ailments with similar symptoms (Remme *et al.,* 2002). Moreover, only a limited number of ontologies are available in the tropical disease domain. Therefore, there is a demand

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*Corresponding author
Email address: segunlatinwo@gmail.com

for the development of more ontologies for the tropical disease domain to represent the domain knowledge in an organized manner (Satria *et al.,* 2012). It is paramount to develop a more detailed semantic taxonomy that can help improve the diagnosis process and broaden the understanding of the domain knowledge with emphasis on the causes, symptoms, and treatments of these life-threatening diseases.

This will make chronic tropical diseases assumptions more explicit and separate the chronic tropical diseases knowledge from the operational knowledge and will also aid the analysis of chronic tropical diseases knowledge. This is important because the lack of an explicitly specified conceptualization often results in poor communication from people to people, from people to computers, and from computers to computers (Hadzic *et al.,* 2005). Therefore, ontologies are suitable to support more effective data and knowledge sharing in the medical field (Pisanelli *et al.,* 1999).

Moreover, with the increasing number of diseases having varying signs and symptoms, it becomes more challenging for healthcare practitioners to remember all information related to the disease. This can result in a wrong diagnosis of chronic tropical diseases which automatically puts the patient's life at great risk. As a result, an ontology based representation of chronic tropical disease is required to represent the entities, ideas and events, along with their properties and relations, as a form of knowledge representation about the medical world.

As a sequel to the aforementioned challenges, an Ontology-Based System for Chronic Tropical Diseases using the METHONTOLOGY approach and Protégé-OWL Tool was developed. However, the complex relationships that exist between the different medical concepts in the tropical disease domain such as causes, symptoms, and treatment are covered by adopting the developed system. The users of this system include computer scientists and healthcare professionals, such as medical physicians, nurses, medical students, travelers, and general patients. It is expected that the result obtained from this study will help in sharing a common understanding of the chronic tropical disease domain knowledge more explicitly.

Moreover, chronic tropical diseases knowledge was elicited through a combination of interviewing, consultations, and documented materials. The elicited knowledge was analyzed using formal concept analysis and the elicited knowledge was used to develop an ontology that formally represents chronic tropical diseases taxonomy, that is, class hierarchies of entities. The developed ontology was implemented using the Protégé-OWL tool. In addition, the implemented ontology was validated using the OWLViz tool and evaluated based on precision, recall, and F-measure as the performance evaluation metrics.

2. Related Work

Medical ontologies have played useful roles in facilitating the re-use, dissemination, and sharing of patient information across disparate platforms. Also, they have been used in semantic–based statistical analysis of medical data. Examples of medical ontologies include GALEN (Rector *et al.,* 1995) and UMLS (Pisanelli *et al.,* 1998). In recent times, researchers in tropical medicine, microbiology, medical nursing, and other related disciplines have been studying the chronic tropical disease domain and concluded that the knowledge of chronic tropical diseases requires information and communication technology tools to develop a general platform for the domain knowledge sharing and reuse (Doerr, 2009). Elicitation and explicit representation of chronic tropical diseases knowledge is required for chronic tropical diseases data analysis, ontology design, and implementation towards ontology building for a chronic tropical disease domain.

Hadzic *et al.* (2005) developed generic human disease ontology (GHDO) to represent the human diseases knowledge and the information of the diseases is organized in four dimensions. This study focused on complex disorders caused by different factors simultaneously. However, the dimension of disease control was not included.

In 2011, Santana *et al.* proposed ontology patterns for tabular representations of biomedical knowledge on neglected tropical diseases. They argued that ontology-like domain knowledge is frequently published in a tabular format. The reuse of such tabular content was investigated in the process of building their ontology where the representation of the interdependencies between hosts, pathogens, and vectors plays a crucial role. The major issues considered in this work were the relationships that existed in the carrier of tropical diseases, the causative vector, and the causative agents that play a major role in the completeness of the ontology developed. After processing they tested the correctness and completeness of the ontology using pre-formulated competence questions as description logic (DL) queries. They observed that the expected results could be reproduced by the ontology and that the proposed approach in their research was recommended for optimizing the acquisition of ontological domain knowledge from tabular representations. This is still contested as it is opined that such a method may not be sufficient for testing other areas in ontology development as variation may exist. If the ontology does not appropriately answer the competency question, a new iteration of the knowledge iteration cycle is initiated which is an overhead in terms of computer overhead.

In a study conducted by Satria *et al.* (2012), a medical ontology for tropical diseases management system was developed. The developed ontology focused on information related to tropical diseases such as dengue, malaria, chikungunya, melioidosis, and leptospirosis. This study considered five tropical diseases, whereas there are about 20 chronic tropical diseases according to the current chronic tropical diseases portfolio. Therefore, the study was inadequate as a developed ontology and this demands an improvement on the existing tropical diseases ontology in order to share a generalized knowledge of the domain.

In 2014, Alamu *et al.* proposed the development of a semantic ontology for malaria using Protégé-OWL software. They opined that the access provided by medical ontologies was cumbersome and the data at the output is often not comprehensive. The authors further argued that this search output are not brief enough to be understood by a non-professional who is just seeking to know or have knowledge in a domain, and the linking of information was also a major problem. Their work came up with a semantic ontology on malaria along with the establishment of a semantic website that enables a less cumbersome mode of access to relevant information gathered. However, this work considered only malaria.

In 2016, Bandrowski *et al.* introduced another dimension in the use of medical ontology: investigations. The authors proposed an ontology that provides terms with precisely defined meanings to describe all aspects of how investigations in the biological and medical domains are conducted. This is a deviation from the nominal use of medical ontology. This research work introduced a multi-level, multi-disciplinary, investigative relationship to the use of ontology.

Studies on the existing medical ontologies show that there are a few ontologies in the tropical disease domain especially in the African region. In addition, the few existing ontologies on chronic tropical diseases are limited in terms of the domain knowledge and do not provide a common and unified structural model for understanding and sharing the domain knowledge. Therefore, there exists a need for an indigenous ontology for chronic tropical diseases and an improvement on the complexity of the existing medical ontologies.

3. Materials and Methods

This study employed the METHONTOLOGY method which provides a framework for ontology development (Figure 1). It also provides specific techniques to perform each activity during the ontology development which is a drawback of other methods. It starts with determining the purpose of chronic tropical disease ontology and the identification of chronic tropical disease domain concepts, identification of associated narrative relations from the domain concepts, hierarchical structuring of the identified concept, hierarchical structuring of the narrative relations, and finally describing formally and axiomatically the concepts, using other concept(s) and narrative relation(s). However, each of the phases can further be refined as the need arises in subsequent iterations.

Chronic tropical disease ontology development phases

Determination of domain and scope
1: Ontology coverage specification
2: Ontology purpose definition
3: Specification of the question types the information in the chronic tropical disease ontology can provide answers to
4: Specification of the chronic tropical disease ontology suitable users (such as chronic tropical disease physicians and researchers) and maintainers (such as annotators and knowledge engineers)

Acquisition of chronic tropical disease knowledge
5: Knowledge on chronic tropical disease is elicited from documented materials and domain experts

Knowledge conceptualization
6: The elicited knowledge is analyzed
7: Based on step 6, the domain entities are classified
8: Using the information in step 7, crucial classes including their relationships and instances (or objects) are enumerated

Representation of domain knowledge
9: Definition of classes and structure of class hierarchy
10. Class hierarchy validation with the domain experts
11. Definition of axioms for each of the classes
12. Definition of axioms for the instances of the classes

Evaluation of the ontology solution model
12. Verification of the axioms for the classes and instances for consistency, completeness, and accuracy purposes
13. The chronic tropical disease ontology is validated by applying the test for questions competency
14: Based on the test performed in step 13, if step 13 is satisfied, then proceed to the documentation phase in step 15, otherwise go to step 5

Documentation of the ontology solution model
15: The formal and informal complete definitions of the chronic tropical disease ontology, including the assumptions and examples are documented

Deployment of the ontology solution model
16: Transfer of the ontology solution model to users
17: The solution model should be made available to the maintainers

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Figure 1.   Stages of development of the proposed chronic tropical disease ontology.

3.1 Chronic tropical diseases ontology development

The process of ontology development is an iterative process (Figure 2). It starts with determining the purpose of chronic tropical diseases ontology and the identification of chronic tropical diseases domain concepts, identification of associated narrative relations from the domain concepts, hierarchical structuring of the identified concept, hierarchical structuring of the narrative relations, and finally describing formally and axiomatically the concepts, using other concept(s) and narrative relation(s). However, each of the phases can further be refined as the need arises in subsequent iterations. This is formally expanded in the algorithm in Figure 2 involving formal concept analysis design tool and Protégé ontology editor to define classes and class hierarchies, value restrictions, relationships between classes and properties of these relationships. The algorithm depicts the process of building the Protégé-OWL ontology for the chronic tropical diseases domain. For every chronic tropical disease object selected, other identifiable related objects or subjects or both with narrative relation(s) found in the domain narratives are noted. For each of the relations identified, a cross-tab relationship was designed using Formal Concept Analysis (FCA) or Relational Concept Analysis (RCA) as the case may be. Finally, each of the identified chronic tropical diseases objects and subjects would be formally described in the Protégé implementation. This process was repeated over a number of iterations until a satisfactory implementation was obtained.

3.2 Development of chronic tropical diseases taxonomy

The development of the chronic tropical disease ontology requires the design of a chronic tropical disease taxonomy. In other to design a chronic tropical disease taxonomy, the analysis of chronic tropical diseases was carried out using the middle-out approach. Starting with the most important concept with subsequent generalization (super-concepts) and specialization (sub-concepts), the Taxo-nomy of Chronic Tropical Diseases was derived (Figure 3). The middle-out approach was adopted for ease and for the convenient comparative advantages it has over the top-down approach (Keet, 2012).

The chronic tropical diseases identified relations for the above narratives, described the narrative relations and object properties for the identified chronic tropical disease objects, and associated the concepts/classes with inverse and equivalent object properties as well as their sampled domain and range (Table 1). These narrative relations were useful in formal descriptions of chronic tropical disease objects, the ontology classes, and their instances as follows:

    i.   Description of the various classes,
    ii.   Assertion of the individuals, that is, the various instances of the classes.

In addition, to enhancing the chronic tropical disease taxonomy, the chronic tropical disease data collected and knowledge elicited were analyzed using FCA with its extension RCA. FCA and RCA were also employed in the design of the Protege-OWL ontology for the domain.

3.3 Formal concept analysis

FCA provides a formal and graphical way to organize data as formal concepts. In a formal context, a pair of a set of objects and a set of attributes that uniquely associate with each other is called a formal concept. A pair (A, B), is called a formal concept in the context $K := \,<G, M, R>$ if and only if $A \subseteq G$, $B \subseteq M$, $A = \overline{B}$, and $B = \overline{A}$. This implies that, (A, B) is a formal concept if the set of all attributes shared by the objects of A is identical with B and on the other hand A is also the set of all objects that have all attributes in B. A is then called the extent and B the intent of the formal concept (A, B) (Ganter *et al.*, 1999).

A context lattice can grow exponentially in the size of the context, and conceptual scaling is one method of reducing the complexity of the resulting diagram. Conceptual scaling is accomplished by considering only a few attributes and concepts at a time as shown in snippets of binary information tables. An example is Table 2.

ChronicTropicalDiseaseOntology Building(ObjectOrSubject, ChronicTropicalDisease)
comment: For each chronic tropical disease subjects or objects identified
for *k* ⟵ 1 to n[ObjectOrSubject]
  comment: Is there any relation with other chronic tropical diseases subjects or objects?
  if *Not* (Exist[IncidenceOrRelation, K])
        then IdentifyAndEstablish[IncidenceOrRelation,K]
        else Note[IncidenceOrRelation, K]
  comment: For each of the incidences/relations identified/noted
  for j ⟵ 1 **to** i[IncidenceOrRelation]
        comment: Design using **FCA**
        DesingUsing**FCA**[j, k]
        comment: Implementation using Protégé
        if *N*ot (Implemented[IncidenceorRelation])
            then ImplementAsObjectProperty[IncidenceorRelation]
        Implement AsClassDesciption[IncidenceorRelation, K]
        Else ImplementAsClassDescription[IncidenceOrRelation, K**]**

Figure 2.   Algorithm for chronic tropical disease ontology.

- © Thing
  - © ChronicTropicalDisease
    - © TropicalPyomyositis
    - © Tuberculosis
    - © Leprosy
    - © Meningitis
    - © Dengue
    - © LymphogranulomaVenereum
    - © Trypanosomiasis
    - © Chikungunya
    - © Rabies
    - © Malaria
    - © Polio
    - © Ebola
    - © Bartonellosis
    - © Cholera
    - © Leishmaniasis
    - © Schistosomiasis
    - © TyphoidFever
    - © Melioidosis
    - © Leptosipiosis
    - © YellowFever
  - © Cause
    - © Bacteria
      - © Fusobacterium
      - © VibrioCholerae
      - © MycobacteriumLeprae
      - © NeisseriaMeningitidis
      - © TubercleBacilli
      - © BartonellaBacilliformis
      - © SalmonellaTyphi
      - © StaphylococcumAureus
    - © Protozoan
      - © LeishmaniaDonwali
      - © PlasmodiumFalciparum
      - © SchistosomaHaematobium
      - © TrypanosomaCruzi
    - © Virus
      - © Rhabdovirus
      - © Filoviruses
      - © Flavirus
  - © OrganismType
    - © Virus
    - © Bacteria
    - © Protozoan
  - © Carrier
    - © Arthropod

- © Dog
- © BodyLice
- © Vector
  - © Ticks
  - © Fleas
  - © Aedes
    - © Mosquito
    - © Cockroach
    - © Insects
    - © Air
    - © Water
    - © FreshWaterSnails
- © Symptom
  - © CardiacFailure
  - © StiffNeck
  - © Covulsion
  - © Headache
  - © AbdominalPain
  - © SubnormalTeperature
  - © Vomiting
  - © Sweating
- © TransmissionMode
  - © BiteOfAnInfectedAnimal
  - © Kissing
  - © TseTseFliesBite
  - © Sneezing
  - © DropletsOfRespiratory
- © Treament
  - © ChloroquinePhosphate
  - © Tetracycline
  - © UseOfVaccine
  - © IntraveneousFluids
  - © AqueousPenicillin
  - © Rifampin
  - © Penicillin
- © TropicalCountry
  - © Nigeria
  - © Cameroon
  - © Colombia
  - © Ghana
  - © Guinea
  - © Angola
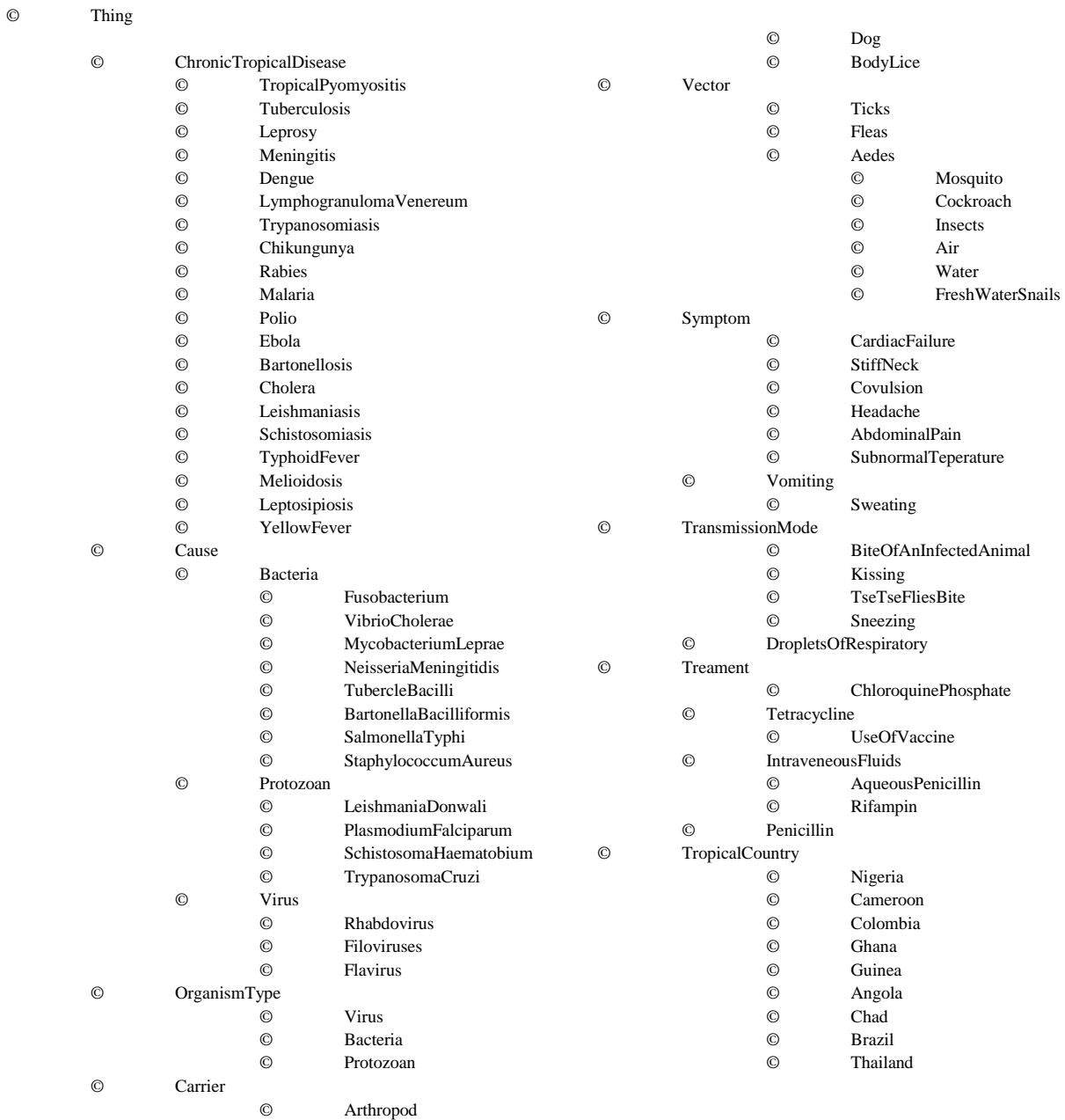 - © Chad
  - © Brazil
  - © Thailand

Figure 3.   Taxonomy of chronic tropical diseases.

Table 1.   Chronic tropical diseases identified relations.

S/N	Narrative Relation	Inverse	Equivalent
1.	*isPrevalentIn*		
2.	*isCausedBy*	*hasCause*	
3.	*isSymptomOf*	*hasSymptomOf*	
4.	*isTransmittedBy*	*hasTransmissionModeOf*	
5.	*isDeathCauseOf*	*hasDeathCauseOf*	
6.	*isTypeOf*	*hasType*	*hasAnExampleOf*
7.	*isTreatedBy*	*hasTreatment*	*isManagedBy*
8.	*isVectorOf*	*hasVector*	
9.	*isDiagnosedBy*	*isToDiagnose*	
10.	*isDeathCauseOf*	*hasDeathCauseOf*	
11.	*isControlledBy*	*hasControlStrategyOf*	

Table 2.　Snippet of Formal Context for the Binary Relation, isCausedBy, in Chronic Tropical Diseases Domain.

isCausedBy	Neisseria Meningitidis	Salmonella Typhi	Tubercle Bacilli	Trypanosoma Cruzzi
Meningitis	X			
Tuberculosis			X	
Ebola				
Typhoid Fever		X		
Trypanosomiasis				X

4. Results and Discussion

The implementation of chronic tropical disease ontology using Protégé-OWL and chronic tropical disease ontology validation and evaluation are discussed in this section.

4.1 Implementation of chronic tropical disease ontology using Protégé-OWL

Ontology implementation with Protégé-OWL 4.3 Editor is an iterative process (Figure 1). The following were derived using the ontology research framework in Figure 1.

i. Chronic tropical disease ontology classes were identified from the chronic tropical disease resources
ii. The narrative relations were identified and defined (Table 3).
iii. The chronic tropical disease ontology classes were arranged hierarchically (Figure 4).
iv. The relations were arranged hierarchically (Figure 5).
v. Each of the chronic tropical disease ontology classes were defined axiomatically (Figures 6 and 7).
vi. Each of the sampled ontology individuals were defined axiomatically.
vii. Chronic tropical disease competency questions were tested (Figures 10 and 11).

4.1.1 Chronic tropical disease ontology classes and class hierarchy

The chronic tropical diseases ontology classes and class hierarchy in this ontology are shown in Figure 4. However, each class and its usage are discussed in this section.

The concepts/classes are subconcepts of *Thing*, which is the starting point in Protege. The concepts are: **Carrier, Causes, Bacteria**, **Protozoan, Virus, Chronic TropicalDisease, OrganismType, Symptom, Transmission Mode, Treatment, TropicalCountry** and **Vector.**

4.1.2 The object property of chronic tropical disease ontology

The derived narrative relations tropical physicians and medical practitioners narratives knowledge elicitation from chronic tropical diseases experts constitutes the OWL object properties. In ontology, properties can be described as the binary relations between a domain and a range. This relation is a subconcept of ***topObjectProperty***, which is the standard starting point in Protégé-OWL Object Property (Figure 5). The Object Properties were defined using domain and range technique as follow: ***isCausedBy, TropicalDisease, isSymptomOf, isTreatedB, isTransmittedBy***, ***isVectorOf, isTypeOf***, ***isPrevalentIn, hasCause, hasSymptomOf, hasTreatment, hasTransmissionMode, hasVector***, ***hasType***.

4.1.3 The chronic tropical disease ontology axioms

The axioms of the chronic tropical disease ontology were divided into two parts: the axioms for classes and the axioms for the individual.

The axioms for classes were used to describe the relationship that exists between the classes, the properties, and the individuals. This section describes the relationships that exist between some of the chronic tropical diseases ontology classes such as **ChronicTropicalDisease.** Also, each of the chronic tropical disease ontology classes were defined axiomatically (Figures 6 and 7).
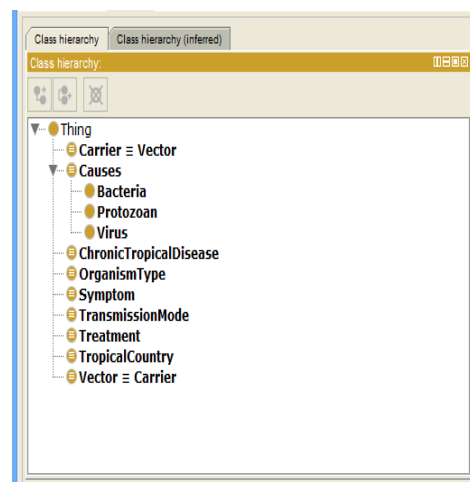

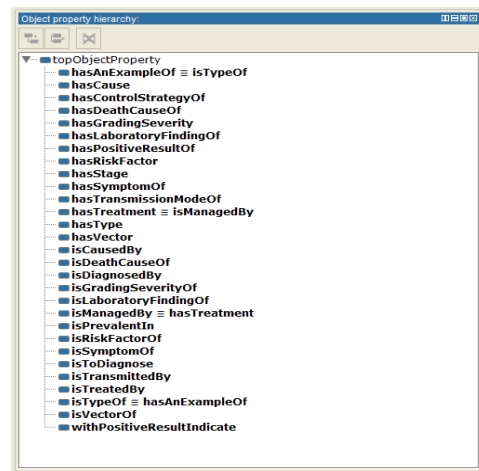Figure 4.　Screenshot of chronic tropical disease class hierarchy.

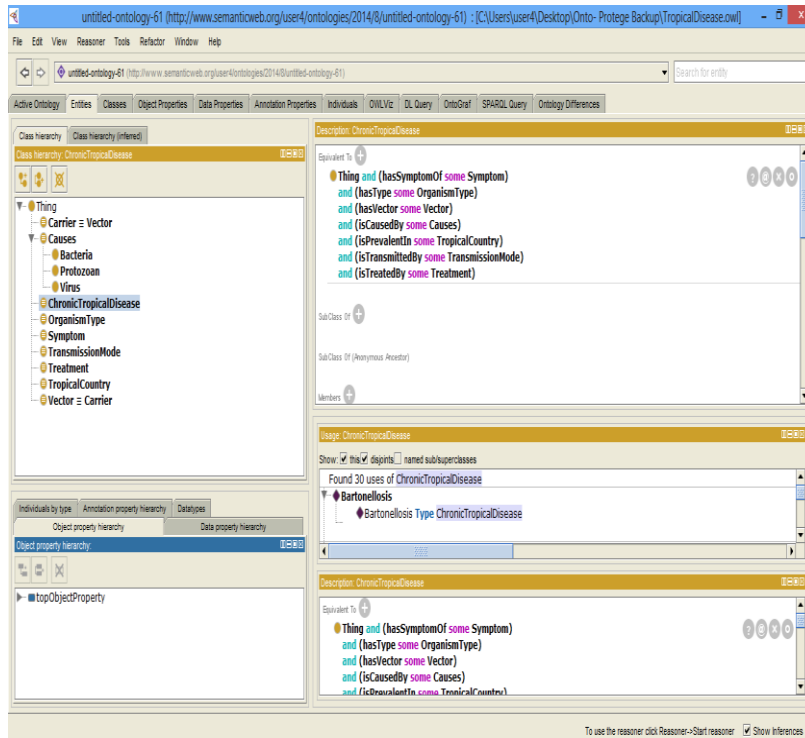Figure 5.　Screenshot of chronic tropical disease object properties hierarchy.

Figure 6. Screenshot of the axiom for class ChronicTropicalDisease.

The axioms of instances are the object properties and data type properties related to every individual such as **Bacteria.**
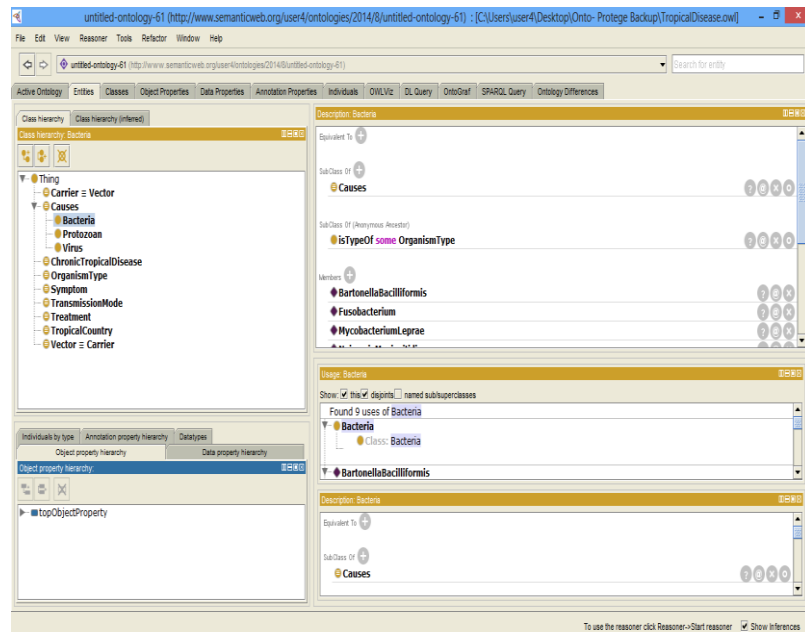

Figure 7. Screenshot of the axiom for class Bacteria.

4.2 Chronic tropical disease ontology validation and evaluation

The OWLViz tool is an ontology graphical visualization tool used for ontology validation. For easy decision making, it is important to represent chronic tropical diseases concepts in a graph-like form. This concept is called visualization in Protégé. The accuracy and completeness validation was done jointly and iteratively by the domain and the ontology experts using the set of competency questions in Table 3. The OWLViz tool was used for ontology graphical visualization (Figures 8 and 9).

Table 3.   Competency questions for chronic tropical disease ontology.

| S/N	Concept	Competency Questions
1	Tropical Country	Chronic tropical diseases that are prevalent in Democratic Republic of Congo are?
		What are the common Chronic Tropical Diseases in Nigeria?
2	Cause	Tropical Ulcer is Caused by?
3	Symptom	What are the Symptom(s) of Meningitis disease?
		What are the Symptom(s) of Tuberculosis disease?
4	TransmissionMode	By what means is Rabies disease transmitted?
		Schistosomiasis is transmitted by?
5	OrganismType	What are the type(s) of Protozoan responsible for Chronic Tropical Diseases?
		What are the type(s) of Virus responsible for Chronic Tropical Diseases?
		What are the type(s) of Bacteria responsible for Chronic Tropical Disease?
		What type of organism is responsible for Meningitis disease?
		What type of organism is responsible for Rabies disease?
6	Treatment	Malaria disease can be treated by?
		Chronic Tropical Diseases treated by Ampicillin are?
7	Vector	By what Vector is Bartonellosis disease carried?
		By what Vector is Ebola disease carried?
		By what Vector is Malaria disease carried?
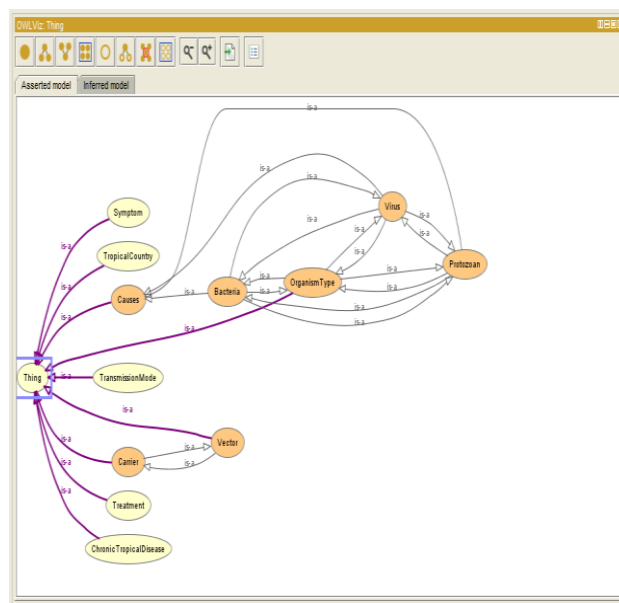
Figure 8.   OWLViz visualization of chronic tropical diseases.
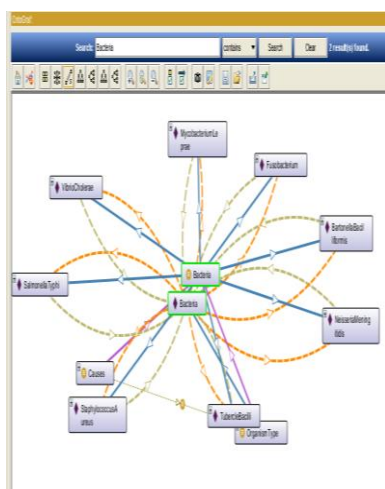

Figure 9.   Ontology graph of **Bacteria**.

In addition, the performance evaluation of the developed ontology was done using the standard ontology evaluation metrics such as Precision, Recall, and F-measure (Frakes *et al.,* 1992; Manning *et al.,* 1999; Rijsbergen, 2007). The fraction of the correctly retrieved relevant results is defined as:

$$Precision = \frac{TP}{TP + FP} \tag{1}$$

$$Recall = \frac{TP}{TP + FN} \tag{2}$$

$$F - measure = \frac{2 \times Precision \times Recall}{Precision + Recall} \tag{3}$$

where:

- TP = True Positive
- FP = False Positive
- FN = False Negative

In this study, the set of competency questions were formalized by expressing them as DL queries (Table 4). The DL queries were implemented as shown in Figure 9 to answer each competency question as:

What are the common chronic tropical diseases in Nigeria?

The resulting values for the applied DL query on the prevalent chronic tropical diseases in Nigeria are: True Positive, TP = 13, False Positive, FP = 0, and False Negative, FN = 0. These results were used to evaluate the ontology using precision, recall, and F-measure as the evaluation metrics. However, this process was repeated for other chronic tropical disease ontology competence questions (Figure 10). Thereafter, the averages for precision, recall, and F-measure for the set of competence questions were determined: 97% for precision, 100% for recall, and 98% for the F-measure. Also, Table 4.2 describes the resulting statistics from the implemented chronic tropical disease ontology. The implemented ontology for chronic tropical diseases meets the objective of representing the knowledge of chronic tropical diseases with an appreciable completeness and accuracy.
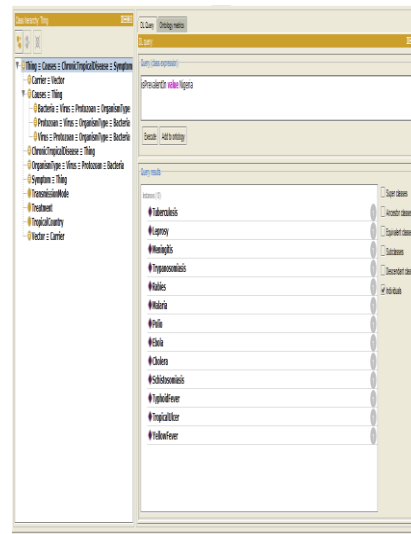

Figure 10. DL Query on the chronic tropical diseases that are common in Nigeria.

Table 4.   Evaluation Results of the DL Queries executed on the chronic tropical disease ontology competency questions.

| S/N	Competency Questions	DL Queries	Precision	Recall	F-measure
1	Chronic Tropical Diseases that are prevalent in Democratic Republic of Congo are?	isPrevalentIn value DemocraticRepublicOfCongo	7/7	7/7	2/2
2	What are the common Chronic Tropical Diseases in Nigeria?	isPreventIn value Nigeria	13/13	13/13	2/2
3	Tuberculosis is Caused by?	hasCause value Tuberculosis	1/1	1/1	2/2
4	Tropical Ulcer is Caused by?	hasCause value TropicalUlcer	1/1	1/1	2/2
5	What are the Symptom(s) of Meningitis disease?	isSymptomOf value Meningitis	8/8	8/8	2/2
6	What are the Symtom(s) of Tuberculosis disease?	isSymptomOf value Tuberculosis	5/5	5/5	2/2
7	By what means is Rabies disease transmitted?	hasTransmissionModeOf value Rabies	1/1	1/1	2/2
8	Schistosomiasis disease is transmitted by?	hasTransmissionModeOf value Schistosomiasis	1/2	1/1	1/1.5
9	What are the type(s) of Protozoan responsible for Chronic Tropical Diseases?	isTypeOf value Protozoan	4/4	4/4	2/2
10	What are the type(s) of Virus responsible for Chronic Tropical Diseases?	isTypeOf value Bacteria	8/8	8/8	2/2
11	What type of organism is responsible for Meningitis disease?	hasType value Meningitis	1/1	1/1	2/2
12	What type of organism is responsible for Rabies disease?	hasType value Rabies	1/1	1/1	2/2
13	Malaria disease can be treated by?	hasTreatment value Malaria	4/4	4/4	2/2
14	Chronic Tropical Diseases treated by Ampicillin are?	isTreatedBy value Ampicillin	3/3	3/3	2/2
15	By what Vector is Bartonellosis disease carried?	isVectorOf value Bartonellosis	5/5	5/5	2/2
16	By what Vector is Ebola disease carried?	isVectorOf value Ebola	2/2	2/2	2/2
17	By what Vector is Malaria disease carried?	isVectorOf value Malaria	1/1	1/1	2/2
	Average		97%	100%	98%
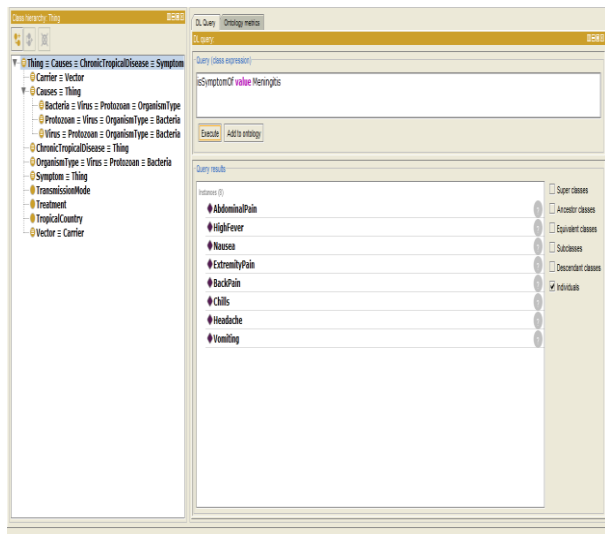
Figure 11. DL Query on the symtoms of meningitis.

5. Conclusions

In computer science and information science, ontology formally represents knowledge as a set of concepts within a domain, and the relationships between pairs of concepts. It can be used to model a domain and support reasoning about entities. Therefore, in this research work, chronic tropical diseases were conceptualized so as to facilitate sharing and reuse of knowledge. In this study, the knowledge of chronic tropical disease resources was elicited through consultation and documented materials. The domain elicited knowledge was analyzed and formally represented using FCA. Protégé editor was used to implement the domain expertise gained as an OWL ontology. In addition, the implemented ontology was jointly validated by both domain and ontology experts for accuracy and completeness using the OWLViz visualization tool. The ontology was evaluated using the ontology evaluation metrics of precision, recall, and F-measure. The evaluation results show that the developed ontology for chronic tropical diseases was able to provide structured information about chronic tropical diseases with 97% average precision, 100% average recall with an average F-measure of 98%. Hence, the implemented ontology for chronic tropical diseases meets the objective of representing the knowledge of chronic tropical diseases domain with an appreciable completeness and accuracy.

Acknowledgements

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