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An ontology scheme for the *yorùbá* traditional medicine knowledge.

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Abstract

Yorùbá Traditional Medicine (YTM) have been mainly observed, practiced and communicated without paying adequate attention to how its knowledge can be standardized and formalized. The goal of this paper is to develop a theoretically-grounded general-purpose computational ontology and tackles a number of conceptual modelling problems in Yoruba world-view. Information related to the use of herbal medicine are scattered across various data sources and they are represented in an unstructured manner. Ontological modelling encourages standardization of terms used to represent knowledge about a domain by providing means to represent conceptual knowledge using expressive formal logics. This paper presents a discussion on the process and product of an experience in developing a formal computational ontology model for the health sector. Particularly, this process was applied to develop ontology for Yorùbá Traditional Medicine.

Keywords: Herbal medicine, ontology, inference, health care, knowledge representation, ontology modularization, semantics web

1. Introduction

1.1 Background information

The study reported in this paper is concerned with formal computational ontology model for representing knowledge in *Yorùbá* Traditional Medicine (YTM). Traditional medicine is a body of knowledge that has been developed and accumulated by indigenous people over thousands of years and it is, concerned with examination, diagnosis, therapy, treatment, prevention and rehabilitation of the general well-being of humans (Ritcher, 2003). Adébísí and Gbagir (2006) stated that herbal medicine is a well-recognized system of medicine throughout the world and is used as remedies for illness such as fever, diarrhea, sore throat, sinus problems, respiratory problems and skin condition.

Nearly 80% of the world population rely on the use of herbal medicines to meet their health care needs and up to 90% of developing world relies on the use of medicinal plants (Sandhya *et. al.* (2006) and WHO (2002)). Drug companies, researchers and organizations also recognize the value of herbal medicine as a source of potential drugs and alternative providers of primary healthcare.

Wangchuk (2008) reported that out of 30,000 human diseases or disorder only one-third can be cured with modern medicines. The reason of this is because of the fact that the drugs available today are not very effective to fight against drug resistant pathogens and newly emerging infections. Therefore, it is important to preserve the value of these medicinal and economical resources and its vast valuable indigenous knowledge. The need to develop computing artefacts for the knowledge in herbal medicine emerges in the context of the development of software for medical decision support system.

Yorùbá Traditional Medicine (YTM) have been mainly observed, practiced and communicated without paying adequate attention to how its ontology can be standardized and formalized. Information related to the use of herbal medicine are scattered across various data sources and they are represented in an unstructured manner.

This research documented here aim at developing a formal computational ontology framework for the representation of concepts, relationships, and axioms/constraints pertaining to *Yorùbá* Traditional Medicine. The rest of the paper is structured as follows. Section 2 situates the concern of this paper within the context of contemporary discourse. Section 3 discusses the main ontology development methodologies and how we have adapted different methodologies to define the *Yorùbá* Traditional Medicine domain ontology. Section 4 is about result and discussion. Finally, section 5 is on conclusion and future research direction.

2 Literature review

Knowledge Representation (KR) is the area of Artificial Intelligence (AI) which covers the method of how knowledge can be best represented symbolically and manipulated in an automated way by reasoning program (Brachman and Levesque, 2003). From the knowledge management perspective, knowledge representation is required to convert *tacit* knowledge to *explicit* knowledge, and to represent the *explicit* knowledge in suitable form to be modelled and applied in knowledge sharing system such as knowledgebase repository or library (Obamsawim, 2006).

The most popular and commonly used knowledge representations technique is logic, which is related to the truth of statements about the world (Amir, 2004). Semantic network and Frame are used to represent knowledge, while the latter is used to represent the real world entity, the former is used to represent inheritable knowledge. Yuanyuan *et. al.* (2010) suggest that ontology can be used to develop the knowledge-base by constructing the ontology model through the relevant concepts and their relationship. Before implementing ontology for Traditional Medicine (TM) on a system, the knowledge must be explicitly and formally represented.

Since ontology has gained recognition from academics and industries, it is used in many different contexts, and has several different definitions. The most widely cited definition is that of Gruber (1993) who defined Ontology as “an explicit specification of a conceptualization”. This definition was modified slightly by Borst *et. al.* (1997) who defined Ontologies as “a formal specification of a shared conceptualization”.

Ontologies are formal in order to be machine process-able and understandable. Ontologies define concepts, properties, and relations explicitly, and are thus explicit specifications. They are shared because they capture knowledge agreed upon by a group and they can be communicated between computers. Finally, ontologies are conceptualizations in that they are abstract models of some phenomenon in the world (Zhou *et. al.*, 2004). Horridge *et. al.* (2009) also define ontology as a hierarchical structure of the term to describe a domain that can be used as a foundation for a knowledge base.

The choice of ontology in this paper is based on its ability to identify classes or concepts, properties and relationships within a domain of discourse. In addition, ontology is an important tool for the organization and contextualization of knowledge, particularly in well bounded context (Maje and Macheal (2003) and Tong (2008)). The importance of ontology has not been adequately utilized in YTM. The goal of Knowledge Representation (KR) is to provide a way to share knowledge of YTM in a machine-readable form, this has not been done, hence, the attempt in this paper.

Description logics (Logic Based Inference) which provides automated support for task related to knowledge management is used in this study. This mechanism provides automated support for the structured representation of terms, concepts and roles (elements of ontology) in a given domain (Diego and Luciano, 2011).

There is not just one correct way for developing ontologies; ontology construction must be supported by software engineering techniques (Falbo, 2004). In general terms, according to Calero *et. al.* (2006), the ontology development methodology can be divided into four recognized phases: specification, conceptualization, formalization and implementation. The goal of the specification phase is to acquire informal knowledge about the domain. The conceptualization phase is to organize and structure this knowledge using external representations that are independent of the implementation languages and environments. The formalization phase transforms the conceptual model and domain ontology into semi-formal representation, this can be done either in Description Logics or UML formalisms (Fahad *et. al.* (2008); Ceccaroni and Kendall (2003)). While in the implementation phase, the semi-formal version of the ontology is formally represented in one of Semantic Web Language with ontology editing platforms. A domain ontology development process is as shown in Figure 1.

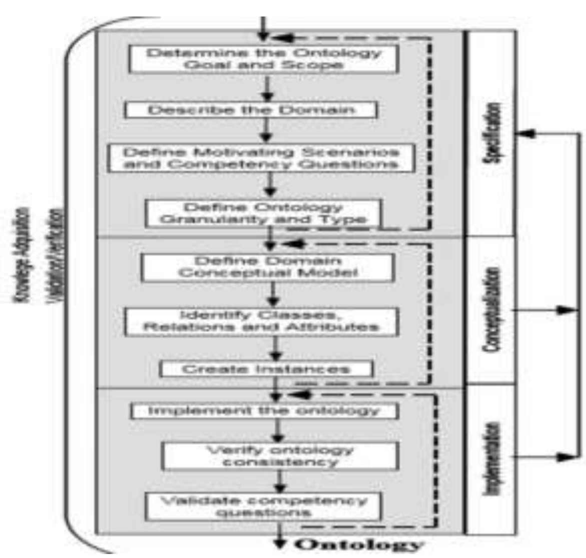


Figure 1: A Domain Ontology Development Process (***Source***: Brussa et al, 2006)

3. Methodology

3.1 Specification phase: domain description

Unlike the Western Medicine which is based on scientifically proven evidences, Traditional medical practices in most cases are based on experience about herbal therapy (explicable) on one hand or on mystical concepts often not understandable to the scientific world (inexplicable) on the other hand, this paper focuses on the former. In this analysis, interactive discussions and participant observations were used during series of visits to practitioners of TM in order to get relevant facts from them, expert professionals from orthodox medicine and software engineers also gave necessary information to support this tasks. To really understand the basic fundamentals of YTM, the following must be well understood:

1. *Yorùbá* **Concept of persons** - Human being è*nìyàn (eni-tı-a-yan)* according to Abímbọ́lá (2006) has often been described in terms of "body" (ara) and "soul" (èmí). The human body (*ara*) is made-up of the outer person or physical body. The soul, to the *Yoruba*, is the "inner person", the real essence of being i.e. its personality (*orí-inú*´), to the *Yoruba* connotes the total nature of its bearer, including the bearer's destiny (*àyànmọ́*) (Ayòdélé, 2002).
2. *Yorùbá* **Concept of Sickness/Illness** - Health-related issues vary slightly from culture to culture, region to region but the basic idea remains similar. Disease to the *Yorùbás* is seen as a disruption of one's connection with the Earth. In the *Yoruba* culture, there are three different dimensions of health. The first is *"ìlera"* which comes from a synthesis of the words *líle*, which means strong, and *ara*, which means body. Ìlera is a functional approach to health. Next is *"san or sunwòn"*, which is concerned with attaining the ideal. Finally there is *àlááfià* which is general well-being (Omotosho, 2016).
3. *Yorùbá* **Concept of healing** - A traditional medical practitioner, in addition to analyzing symptoms of the patient, look for the emotional and spiritual causes of the disease to placate the negative forces and only then will the proposed treatment that he/she deems appropriate. This may include herbs in the form of an infusion, enema, etc. In YTM, they also use dances, spiritual baths, symbolic sacrifice, song/prayer, and a change of diet to help cure the sick including the root cause of the problem and seek to eliminate it (holism).
4. *Yorùbá* **Concept of medicine and its therapeutic processes** - Most of the herbal drugs in YTM are either single or mixture of leaves, root, bark of trees or shrubs, fruits etc. Also it can go in combination with animal parts and minerals. The herbal composition can be grounded or chopped into desire sizes (à*gúnmu*), it can be in form of cream (*ìpara*) or liquid form (*àgbo*) which can be drank, injected, rubbed, eaten and so on based on the experience of the practitioners (Oladosu *et. al.*, 2012).

3.2 Conceptual phase: domain conceptual model

The YTM conceptual model was transformed into a formal model by writing it in a formal form. Figure 2 shows conceptual model diagram for the *Yorùbá* Traditional Medicine. The necessary concepts and the relationships between the classes are shown. Example of such concepts include Disease, Herbal Medicine, Plant Parts, Animal Product, Mineral Resources etc. and the relationships include isUsedBy, isA, treatWith, partOf, isUseToTreat etc. These are shown in an hierarchical form.

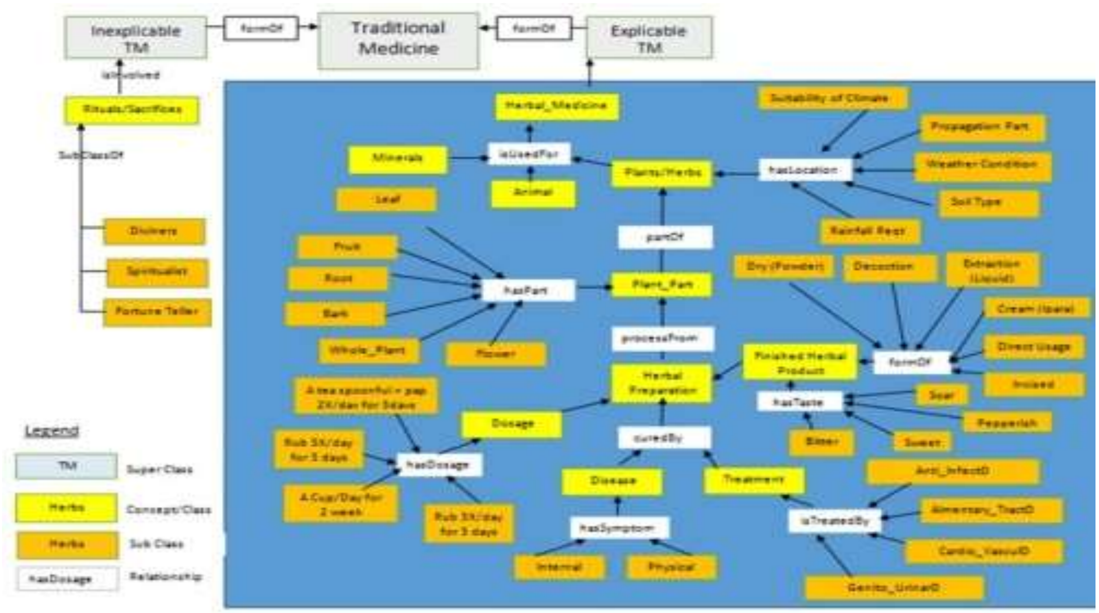


Figure 2: *A Proposed Conceptual Model for Yoruba Traditional Medicine Ontology*

3.3 Domain formalization

3.3.1 Definition of axiom

The inference procedures implemented in computational reasoners aim at realizing the entailment relation between logical statements (Russel and Norvig, 2003). They derive implicit statements from a given knowledge-base or check whether a particular statement is entailed by a knowledge-base. In this section, we present the transformation of the domain ontology into its formal representation, using Description Logics (DLs). Description Logic Language syntactically is expressed as;

$DL = (T, \bot, \neg A, C \cap D, C \cup D, \forall r.C, \exists r.C)$ where:

T = Universal Concept

$\bot$ = Bottom Concept

$\neg A$ = Atomic Negation

$C \cap D$ = Intersection

$C \cup D$ = Union

$\forall$ r.C = Value Restriction and

$\exists$ r.C = Limited Existential quantification that declares the existence of a relationship (or Role) to a concept C (called existential role restriction).

This subsection describes how rules work and what the results of inference indicate. Inference rules were designed to derive desired results as shown below.

[Result: 1] - *Yorùbá* herbs which can be used for treating patient's symptom.

[Result: 2] - *Yorùbá* herbs which are located in the user's living place and can be used for treating user's symptom.

[Result: 3] - *Yorùbá* herbs which users have preferred/unpreferred tastes.

The following is a rule (Rule: 1), which can derive *Yorùbá* herbs and satisfies [Result: 1]

Rule 1: **goodForTheSymptom**

(1)

[Rule: 1] consists of 2 parts. The left side of an arrow is antecedent, and the right side is consequent. The hasSymptom

hasGood*Yorùbá*HerbForTheSymptom, and treats are all properties which are represented on the ontology. The characters which start with **'?'** are variables and they are all instances of the classes which are defined on the ontology. Thus, the rule whose name is goodForTheSymptom means that if *p* has symptom *s* and *h* treats *s*, then *p* has good *Yorùbá* herb *h* for the symptom. If the antecedent is satisfied, the rule gets fired, then the property hasGood*Yorùbá*HerbForTheSymptom gets asserted between instances of Patient and *Yorùbá*Herb classes. This shows how the rule works and properties are asserted by inferences.

[Rule: 2] is a rule to derive *Yorùbá* herbs which are located in the living place of the patient,

[Results: 2].

hasSymptom(?p, ?s) ∧ treat(?h, ?s)

⇒ hasGoodYorubaHerbForTheSymptom(?p, ?h)

Eq. 1

Rule 2: **good*Yorùbá*HerbLocatedinTheLivingPlace** (2)

The property hasGood*Yorùbá*HerbForTheSymptom is inferred in [Rule: 1]. Therefore [Rule: 2] is executed after the inference of [Rule: 1]. If the result of [Rule: 1] is none, the result of [Rule: 2] is also none either.

[Rule: 3] is the rule which derives has*Yorùbá*HerbWithRatedTaste property.

hasGood*Yoruba*HerbForTheSymptom(?p, ?h) ∧ isLivingIn(?p, ?l1)

∧ isLocatedIn(?h, ?l2) ∧ isPartOf (?l1, ?l2)

⇒ hasGoodYorubaHerbLocatedInTheLivingPlace(?p, ?h)

Eq. 2

Rule 3: ***Yorùbá*HerbWithRatedTaste** (3)

Yorùbá herbs are rated by the patient from the results of [Rule: 3]. Therefore, the result of [Rule: 3] is [Result: 3]. The [Rule: 4] and [Rule: 5] will be executed after the execution of [Rule: 3] as shown in Figure 3, Because [Rule: 4] and [Rule: 5] need the results of [Rule: 3] which mean that *Yorùbá* herbs are rated by the patient.

isRatedBy(?t, ?p) ∧ hasTaste(?h, ?t)

⇒ hasYorubaHerbWithRatedTaste(?p, ?h)

Eq. 3

Rule 4: ***Yoruba*HerbWithPreferredTaste** (4)

has*Yoruba*HerbWithRatedTaste(?p, ?h2) ∧ hasTaste(?h1, ?t1) ∧ hasTaste(?h2, ?t2) ∧ isPreferredBy(?t2, ?p) ∧ isTheSameTasteAs(?11, ?t3) ∧ isTheSameTasteAs(?t2, ?t3) ⇒ hasYorubaHerbWithPreferredTaste(?p, ?h1)

Eq. 4

Rule 5: *Yorùbá***HerbWithUnPreferredTaste** (5)

Rule *Yorùbá*HerbWithUnpreferredTaste

The results of [Rule: 4] and [Rule: 5] are [Result: 3]. After the derivation of 2 properties which are inferred by [Rule: 4] and [Rule: 5].

has*Yoruba*HerbWithRatedTaste(?p, ?h2) ∧ hasTaste(?h1, ?t1) ∧ hasTaste(?h2, ?t2) ∧ isNotPreferredBy(?t2, ?p) ∧ isTheSameTasteAs(?t1, ?t3) ∧ isTheSameTasteAs(?t2, ?t3) ⇒ hasYorubaHerbWithUnpreferredTaste(?p, ?h1) Eq. 5

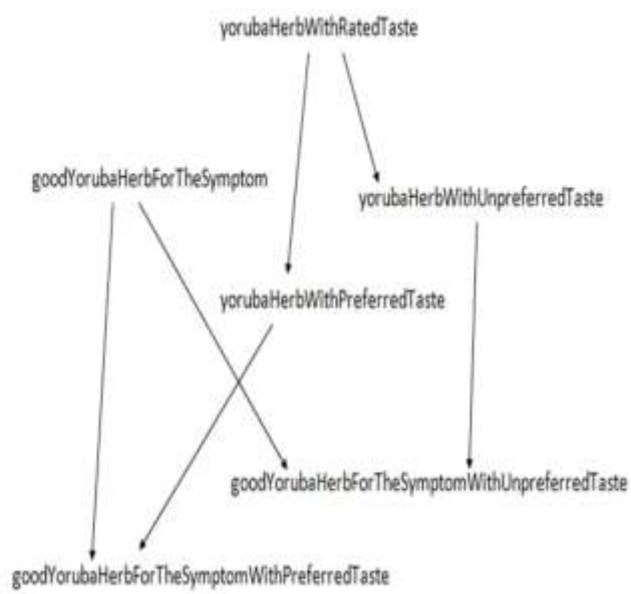


Figure 3: Inference Chains (Source: Kato *et. al.* (2010))

In the new system, an idea of ontology was employed to represent domain knowledge that expresses the semantics of each class and its relations.

There are several classes in the ontology such as SpiritualTherapy, HerbalTherapy, HerbalPreparation, HerbalFinishedProduct, HerbalTaste, PlantPart, Dosage and HerbLocation. The SpiritualTherapy class represents a way of treating patient with ailment in the system. The HerbalTherapy class expresses the method used to treat patient by using single or compound herbs or combine

with animals and minerals. Herbal Preparation class represents the processes involve in converting herbs to the form to cure ailment. Herbal Finished Product class is the product gotten from herbal preparation. Plant Part class means the parts that can be used for herbal preparation. Dosage class represents the frequency and quantity to be used to treat disease. The Herb _Location class means living places of users and locations of *Yorùbá* herbs. Other classes such as Herbal Taste which shows what tastes the *Yorùbá* herbs have. The subclasses of Taste are all tastes (Acerbic, Acrid, Bitter, Spicy, Insipid, Sour, Sweet) of *Yoruba* herbs. However, users have individual preferences of tastes. Thus, *Yorùbá* herb's tastes was represented in Herbal Taste subclass. Patient, Symptoms, Disease, Herb Application and so on are other subclasses under YTMO.

4 Implementation phase:

4.1 Ontology visualization and query

In order to implement the ontology, we chose Protégé 4.3 because of the fact that it is extensible and provides plug-and-play environment that makes it a flexible base for rapid prototyping and application development (Knublauch *et. al.*, 2005). YTMO classes, object properties and data properties were created. To compare the ontology implementation with its conceptualization, graphics using the OWL-Viz and OntoGraf plug-ins were generated. OWL-Viz enables the class hierarchies in OWL ontology to be viewed, allowing comparison of the asserted class hierarchy and the inferred class hierarchy. In this, defined classes can be distinguished and inconsistent concepts are highlighted in red. Figures 4 and 5 show the domain ontology taxonomy and the ontology visualization.

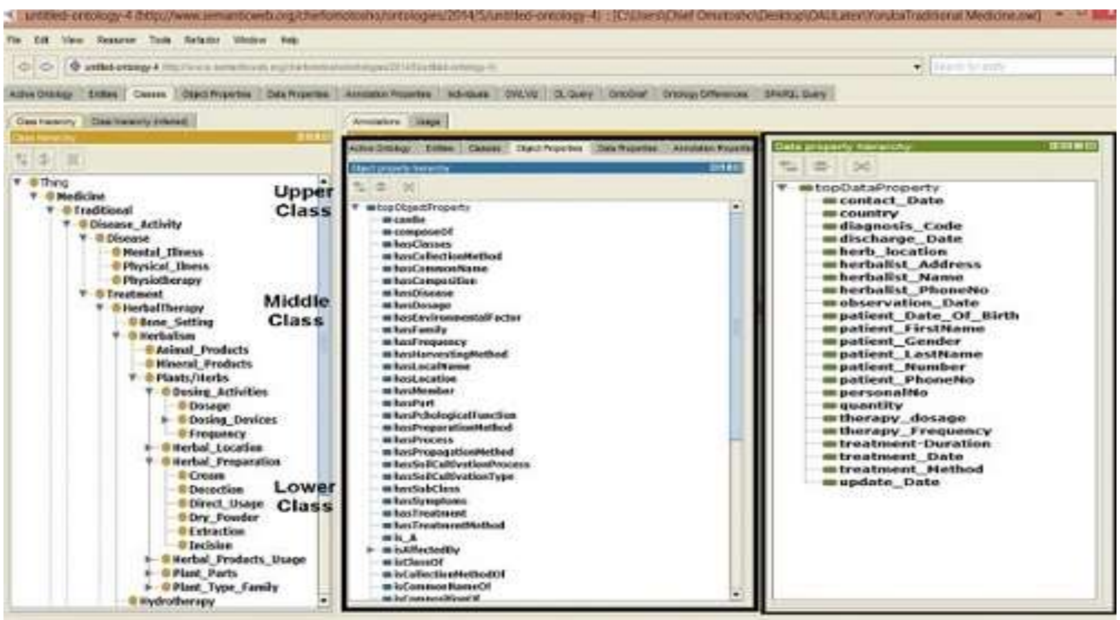
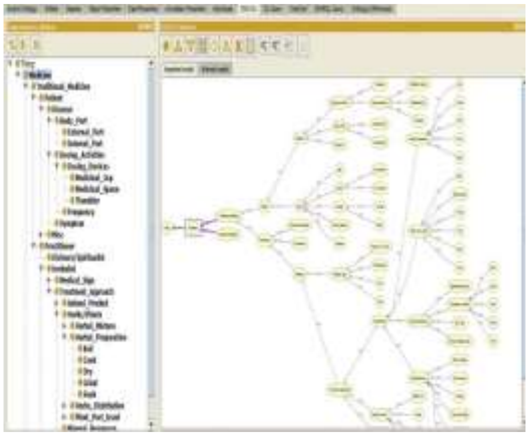
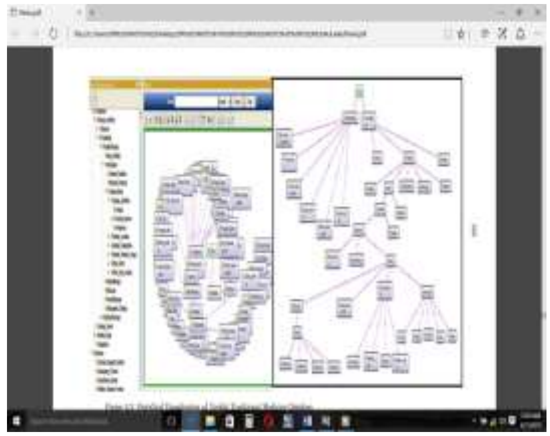


Figure 4: *YTM concepts, object properties and data properties.*



5a

Figure 5a: *YTM* concepts and Owlviz.



5b

5b:OntoGraf Visualisation of YTM Ontology

In order to verify the accuracy of the ontology, DL query was used to test for the satisfiability of the ontology. The result is as shown in Figures 6 and 7.

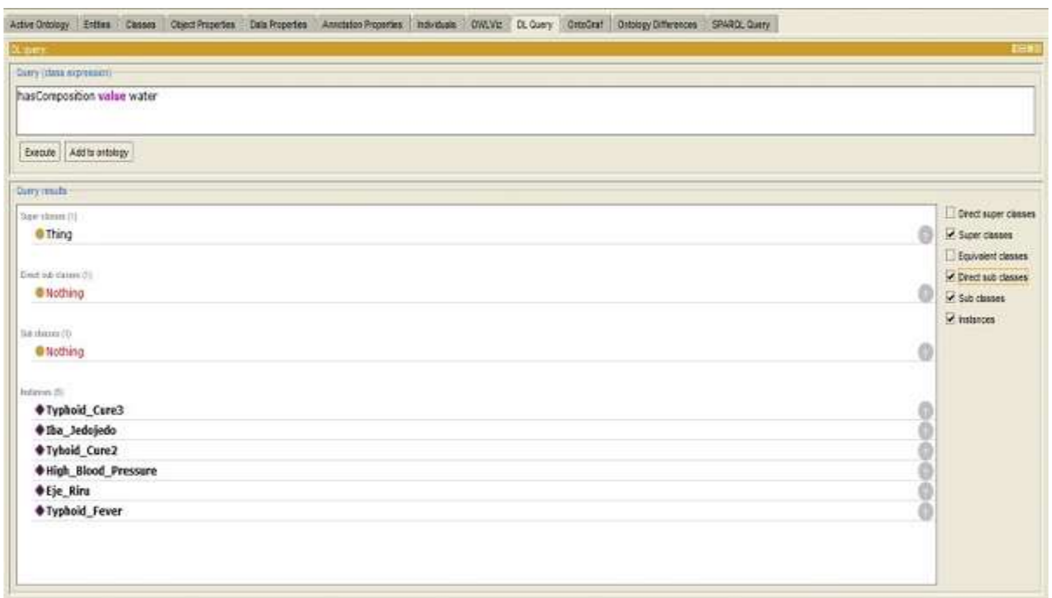


Figure 6: Query about Diseases having Composition 'Water'.

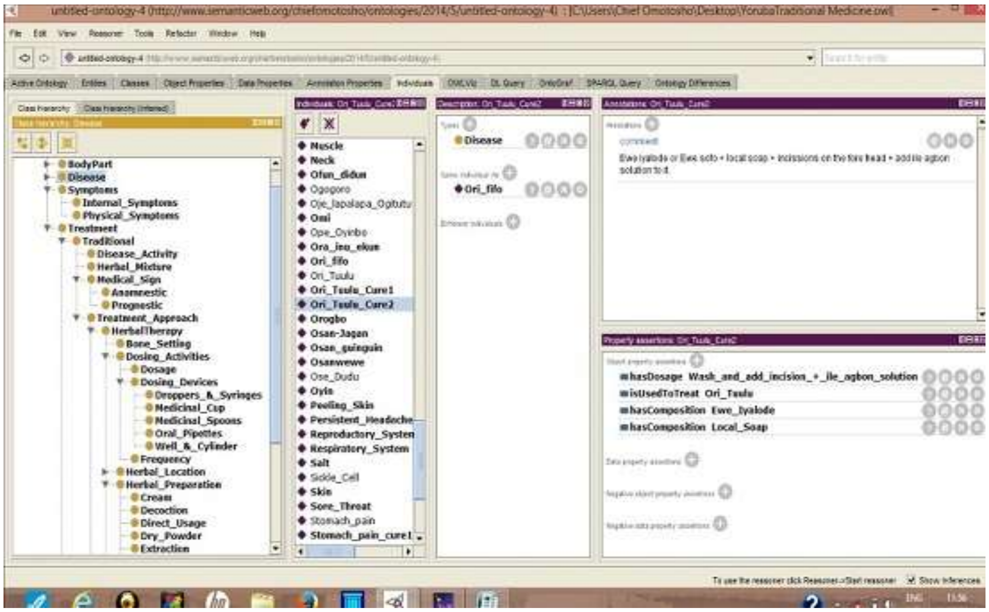


Figure 7: YTMO Instances.

5. Conclusion and future research direction

Based on the above and considering the need to use the prototype for the development of computing artefacts such as software development is evident. The ontology development methodology has been followed and the verification and validation have been carried out, taking into account that partial verification allow identifying errors propagation between set of classes. Furthermore, for the purpose of making the ontology more flexible and allow extensibility and reuse, it is important to modularize the ontology if possible. In this paper, we have demonstrated the technical aspects and features of the ontology construction. Particularly, this approach has been used to define a domain ontology for YTM, which could be extended by task ontologies and used by different medical applications.

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