Building a Herbal Medicine Ontology Aligned with Symptoms and Diseases Ontologies

Bassel Alkhatib, Dania Briman
Arab International University
Syrian Arab Republic
b-khateeb@aiu.edu.sy
danea1980@hotmail.com

Journal of Digital Information Management

ABSTRACT: *The use of traditional medicine is increasing rapidly in many societies due to its efficiency and affordability. The locally available herbs are basically used in the treatment of symptoms and diseases. Herbal Medicines have proved effective in many cases and outperformed the chemical drugs.*

Subsequently, the need arose to develop an herbal repository containing the taxonomy hierarchy that represents the structured knowledge of herbs and could be integrated in many medical applications that use the herbs in the treatment in an accurate and effective way.

Today, Medical ontologies have become the most efficient way for representing declarative knowledge about diseases, symptoms, medications, and diagnosis.

Many ontologies have been elaborated in the few past years for some well-known traditional medicine like the Chinese, African and Korean traditional medicine.

Few of these existing ontologies tried to relate traditional medicine ontologies with known "modern" medical ontologies.

Linking traditional medicine ontologies with medical ontologies can benefit in the treatment process where herbs can be used effectively.

In this paper, we are proposing a new ontology to be used for the herbal medicine. We are also introducing an algorithm to align our ontology with the symptoms ontology SYMP and with the diseases ontology DOID. The MeSH ontology is the source of our herbal concepts.

We are actually using this ontology in an educational expert system that prescribes herbs for the treatment of casual symptoms. In addition, new herbal blends can be suggested, and conflicting herbs effects can be detected through this system. A simple e-health portal has been developed to interact with the expert system.

Subject Categories and Descriptors
I.2.1 [Applications and Expert Systems]; Medicine and science:
J.3 [Life and Medical Sciences]; Medical information systems

General Terms: Ontology, Medical Information Systems, Medical Information Processing

Keywords: Herbal Medicine, DOID, SYMP, MeSH, Ontology Modeling, Ontology Engineering, Ontologies Alignment, Semantic Technology, Expert Systems

Received: 21 September 2017, Revised 2 November 2017, Accepted 16 December 2017

DOI: 10.6025/jdim/2018/16/3/114-126

1. Introduction

Traditional medicine, based on herbs, can be used to enhance access to health care in many countries. An avenue to ensure the safety and the efficacy of traditional medicine is by integrating traditional medicine with the formal health system, which can improve the follow-up process. This integration can be realized by aligning medical knowledge structures with traditional medicine knowledge structures in order to achieve the semantic interoperability.

Researches has been conducted in this field in the last years; most of the previous work focused on building stand-alone traditional medicine ontologies that link herbals with the treatments of diseases. However, there are no proposed ontology that links herbs with diseases symptoms.

In this paper, we present an ontology that consists of a new conceptual structure called HERBAL-MEDICINE that uses the MeSH[1] ontology, proposed by the World Health Organization (WHO), as resource of herbal concepts. We also introduce an alignment algorithm to align both of the well-structured diseases ontology DOID[2] and the symptoms ontology SYMP[3], with our ontology.

This paper is organized as follow: Section 2 presents a brief summary of previous related works with some reviewing points; Section 3 describes our approach for building the herbal medicine ontology, and the used algorithm to align the ontology with symptoms and diseases ontologies. The expert inference rules are shown with some examples in Section 4. The practical application through an e-health portal, the system architecture, and the user interface are presented in Section 5; the paper concludes in Section 6.

2. Related Work

Many researches focused on the development of traditional medicine ontologies belonging to a specific culture. For example, [1] developed an ontology for the traditional Korean medicine comprising symptoms, diseases, and treatments. This work "*provided a method for sharing traditional Korean medicine ontology knowledge in a machine-readable format and created a treatment support system using this knowledge. In particular, ontological knowledge was used to suggest the disease and treatment, to support the diagnosis and treatment and to provide a means of sharing the treatment knowledge among many users*".

However, this work did not consider the side effects of the traditional medicines, and did not align with well-known diseases ontologies. Even though, he has indicated the importance of doing this link, "*the treatment information should be linked to the disease ontology of traditional medicine as well as to the disease ontology of modern medical science. Knowledge of medicinal treatments in traditional medicine will be useful due to their relationship to diseases*" [1].

Another effort is done to build the Kampo ontology for the traditional Japanese medicine [2]. *"It provided taxonomic and chemical information for 158 crude drugs and 348 prescriptions of the traditional Kampo medicine in Japan*".

This work focused on the "*resolution of discrepancy between biochemical knowledge such as molecular interaction/function and medical knowledge such as hypo/hypertensive activity*" [2]. Similar to the previous work, there are no link with well-known diseases and symptoms ontologies.

Many works has also been conducted to develop an ontology of the Thai herbal knowledge. One of these works is presented by [3] that aims to build an ontology that "*express the relations between provinces, persons, symptoms, anamnesis and Thai herbs*". This work was interested in "*developing an e-health advice system to provide user who wants to treat diseases using Thai herbs*". This work uses a relationship between persons and symptoms through the has_symptom relation, but there is no explicit relations between symptoms and diseases.

Another work is presented by [4], where they added the "Taste" concept and linked it with the person concept and the Thai herb concept. However, they did not link with known diseases and symptoms ontologies. In addition, their added concepts are specific making difficult to use their ontology for general purposes.

[5] proposed an ontology for the African traditional medicine, linked to medical and plant ontologies. This work was further enhanced by [6]. Finally, [7] designed an ontology for the African Traditional Herbs. The goal of this research was "*to formulate and implement a robust herbal drugs/medicine database ontology framework for Yoruba traditional medical services from which physicians can have knowledge of herbal medicines (drugs) and can infer knowledge about traditional drug prescriptions and cure for ailments and diseases*". However, the research did not pay attention of the relation between symptoms and herbal medicines via the cause relationship to avoid side effect of herbal medicine.

[8] and [9] proposed a large-scale domain ontology for the Traditional Chinese Medicine (TCM) that aims to overcome the problem of the semantic heterogeneity; however, this ontology is not available to the public. TCM is rich in semantic modeling, where multiple efforts on semantic web and ontologies of TCM are available [10].

A newer work done by [11] for the Unani Medicine ontology. It covered "*upper level domain knowledge of Unani medicine that includes core principles, symptoms, diagnoses, patient, treatment and, disease. It helps researchers, academicians and Unani medicine practitioners to share their common understanding of the domain*". This work focused on the structure of the Unani medicine concepts, and mentioned the possibility of linking with existing ontologies of traditional medicine in the future.

2.1 Critical Review

Most of the previous works assume that herbs cure diseases, without considering symptoms neither those

[1]http:// www.ncbi.nlm.nih.gov/mesh

[2]http://purl.obolibrary.org/obo/DOID_4

[3]http://www.berkeleybop.org/ontologies/symp.owl

that can be cured by herbs, nor those that might cause by herbs (side effects). In fact, herbs are most often more suitable for treating symptoms than treating diseases.

"The scientific evidence for the use of herbal remedies is often conflicting and although the symptoms of some illnesses improve with some herbal remedies, the best evidence doesn't prove that herbal remedies cure illnesses." [12]. The relations (cure, cause) can be used to infer new herbal blends as a complementary treatment for some diseases. In addition, these relations can help suggesting herbal remedies for some casual symptoms taking into account the symptoms of patient's chronic diseases. Finally, these relations can be also used to detect conflicting effects of herbs.

However, none of these benefits can be achieved unless the relationships between herbs, symptoms and diseases are explicit.

In addition, most of the previous works did not pay attention to align with some herbal medicine ontology that explicit the composition of herbal medicines. We know that herbal medicines are composed of herbs. Therefore, one can infer the side effects of an herbal medicine depending on herbs that are composing it.

In most works, herbal concepts are added without aligning with some well-known ontology as the MeSh ontology for example.

There are two OBO (Open Biological and Biomedical Ontologies) that can be used for general diseases diagnosis if their classes and properties are aligned properly. The diseases ontology DIOD and the symptoms ontology SYMP. There were few attempts to develop ontologies for diseases diagnosis (e.g. TMO4, Galen5, HPO6, IDO7), but it reveals that they are dedicated for specific purposes and cannot be used for diseases diagnosis in general [13]. Internationally, there are countless existing biomedical vocabularies such as SNOMED-CT8, LOINC9, ICD-9 CM10, MeSH and UMLS11. Many of these existing biomedical vocabulary standards rest on incomplete, inconsistent, or confused accounts of basic terms pertaining to diseases, diagnoses, and clinical phenotypes [13].

There are some ongoing attempts to update the human diseases ontology to include symptoms, and to explicit the relations between those symptoms and diseases. Therefore, there were some models proposed for such undertaking. [14] designed an ontology model, called Generic Human Disease Ontology (GHDO), that relates diseases to symptoms (phenotypes) and to the other three elements that uniquely identify a disease: disease type, causes, and treatments. However, no GHDO ontology has been published from the proposed model. Finally, a newer research by [15] proposed an alignment algorithm to align the diseases ontology (DOID) with the symptoms ontology (SYMP) creating a core diseases symptoms ontology (DSO) that can scale to any number of diseases and symptoms. Actually, the core DSO links only some few diseases to their symptoms.

3. Proposed Approach for Ontology Modeling

3.1 The WHO Categorization

The world health organization (WHO) defines the following terms:

• **Herbal Medicines:** Herbal medicines include herbs, herbal materials, herbal preparations and finished herbal products that contain as active ingredients parts of plants, or other plant materials, or combinations.

• **Herbs:** Crude plant material such as leaves, flowers, fruit, seed, stems, wood, bark, roots, rhizomes or other plant parts, which may be entire, fragmented or powdered.

• **Herbal Materials:** In addition to herbs, fresh juices, gums, fixed oils, essential oils, resins and dry powders of herbs. In some countries, these materials may be processed by various local procedures, such as steaming, roasting, or stir-baking with honey, alcoholic beverages or other materials.

• **Herbal Preparations:** The basis for finished herbal products and may include comminuted or powdered herbal materials, or extracts, tinctures and fatty oils of herbal materials. They are produced by extraction, fractionation, purification, concentration, or other physical or biological processes. They also include preparations made by steeping or heating herbal materials in alcoholic beverages and/or honey, or in other materials.

• **Finished Herbal Products:** Herbal preparations made from one or more herbs. If more than one herb is used, the term mixture herbal product can also be used. Finished herbal products and mixture herbal products may contain excipients in addition to the active ingredients. However, finished products or mixture products to which chemically defined active substances have been added, including synthetic compounds and/or isolated constituents from herbal materials, are not considered to be herbal.

3.2 Constructing the Conceptual Structure of the Herbal Medicine

[4]http:// code.google.com/p/translationalmedicineontology

[5]http://www.co-ode.org/galen

[6]http:// www.human-phenotype-ontology.org/index.php/hpo_browse.html

[7]http:// infectiousdiseaseontology.org/page/Main_Page

[8]http://www.openclinical.org/medTermSnomedCT.html

[9]http://loinc.org

[10]http://icd9cm.chrisendres.com

[11]http:// www.nlm.nih.gov/research/umls

According to the previous categories, we constructed the herbal medicine conceptual structure that consists of the Herbal Medicine as the main class; all other concepts (Herb, Herbal Material, Herbal Preparation and Finished herbal product) are subclasses of the Herbal Medicine class. In addition, Herbal Material, Herbal Preparation and Finished herbal product are composed of Herb. See Figure 1.

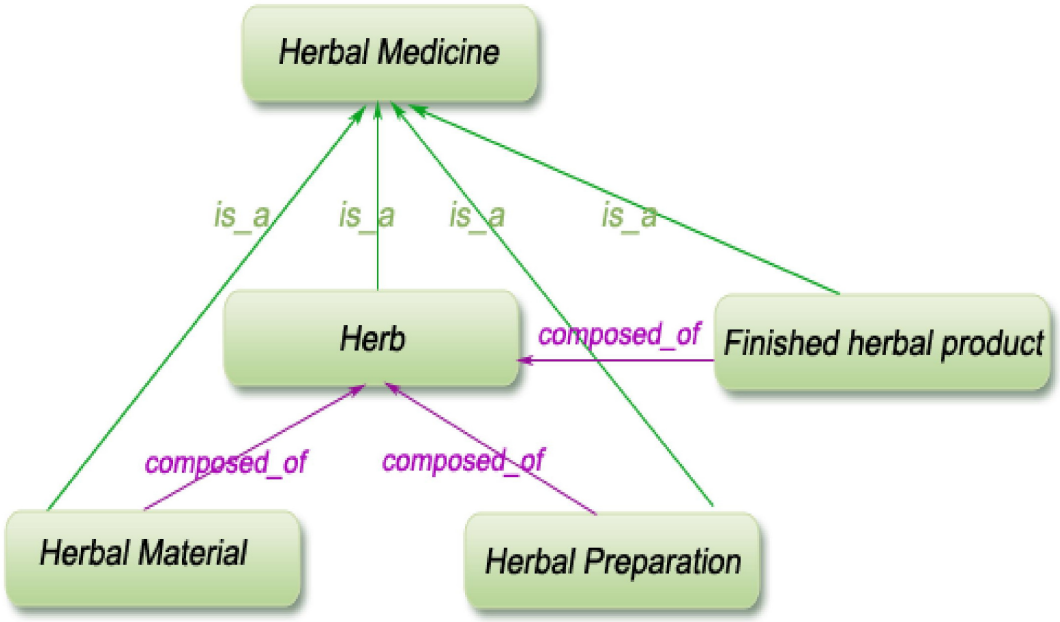

Figure 1. Conceptual structure of the Herbal Medicine

We defined the following attributes for the Herbal Medicine:

Label	Synonym	Description	Definition
Part_used	Warning	Composition	Dosage
Toxicology	Medicinal uses	Commercial preparation	

3.3 Selecting an appropriate Ontologies Alignment Method

Ontology alignment is the combining of two (or more) ontologies into one, and defining relationships between the concepts of the ontologies forming a new ontology at the end. Alignment between ontologies is a critical challenge for the semantic interoperability [9] as well as for producing hybrid ontologies [16]. There are mainly two approaches for aligning ontologies: Ontology Matching and Ontology Linking.

Ontology matching techniques are appropriate for relating ontologies that are on the same domain or on partially overlapping domains. For example, they can be used to align two different diseases ontologies [17].

Ontology linking allows elements from distinct ontologies to be coupled with links [17]. For example, ontology linking is appropriate for aligning diseases and symptoms ontologies as diseases and symptoms are separate concepts.

3.4 Proposed Algorithm for building Herbal Medicine Ontology (HMO) and aligning with the Symptoms Ontology (SYMP) and with the diseases ontology (DOID)

The proposed algorithm comprise the following steps:

Step 1: Align herbs with symptoms contained in the SYMP ontology: In this step, symptoms of the SYMP ontology are added to the HMO ontology. Herbs that cure symptoms are added to the ontology using the relation **cure** (herbs concepts are imported from the MeSH ontology).

```
Algorithm Align_Herb_with_Symptom(SYMP Ontology){
For all symptoms S ∈ SYMP {
    Add S to HMO
    Fetch all Herbs cure S from some reliable resource
    For all H ∈ Herbs {
     For all herbs H1 ∈ MeSH ontology {
     IF ( ( H1.name or H1.synonyms) == H){
```

```
          Add H1 to HMO
          Add (H1 is_a Herb) to HMO
          Add (H1 cure S) to HMO
        } //IF
      } //For all herbs
    } // For all H
 Fetch all Herbs cause S from reliable
resource
   For all H ∈ Herbs {
      For all herbs H1 ∈ MeSH ontology {
        IF ( ( H1.name or H1.synonyms) ==
H){
            Add H1 to HMO
            Add (H1 is_a Herb) to HMO
            Add (H1 cause S) to HMO
         } //IF
      } //For all herbs
    } // For all H
  } //For all symptoms
 Out HMO
}
```

Step 2: Align herbal materials with symptoms: Herbal materials that cure symptoms (that have been added to HMO in the previous step) are added to HMO. For each added herbal material, herbs that compose this material is also added to the HMO (if not already exist).

```
Algorithm Align_Herbal_Material_with_
Symptom
    (SYMP Ontology, HMO Ontology) {
    For all symptoms S ∈ HMO {
   Fetch all Herbal-Material cure S from
some reliable resource
    For all HM ∈ Herbal_Material {
     Add HM to HMO
     Add (HM is_a Herbal_Material) to HMO
      Add (HM cure S) to HMO
       IF HM composed_of more than one
       herb {
         For all H ∈ HM :
            Add (H is_a Herb) to HMO
            Add (HM composed_of H) to HMO
         } //For all H
   } //If
}//For all HM
Fetch all Herbal-Material cause S from
some reliable resource
For all HM ∈ Herbal_Material {
  Add HM to HMO
  Add (HM is_a Herbal_Material) to HMO
  Add (HM cause S) to HMO
  IF HM composed_of more than one herb {
     For all H ∈ HM :
        Add (H is_a Herb) to HMO
        Add (HM composed_of H) to HMO
      } //For all H
    } //If
  }//For all HM
  } //For all symptoms
  Out HMO
}
```

Step 3: Repeat Step 2 for the herbal preparations, and then for the finished herbal products.

Figure 2. shows the resulting relations between herbs and symptoms in this stage.

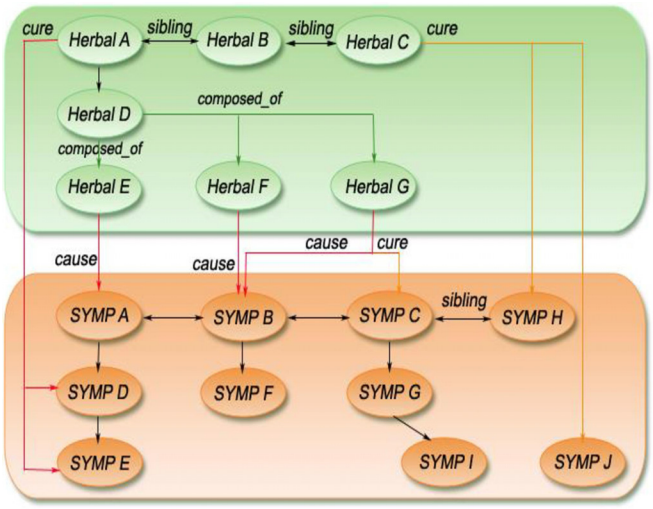

Figure 2. Herbs and Symptoms

Step 4: Align HMO symptoms with the diseases symptoms from the DOID ontology.

```
Algorithm Align_Symptoms_with_Diseases(
DOID Ontology, HMO Ontology){
For all Symptoms S ∈ HMO {
```

```
For all Diseases D ∈ DOID {
   Add D to HMO
   IF D has_symptom S
    Add (D has_symptom S)
 }//For all Diseases
 }//For all Symptoms
 Out HMO
 }
```

Figure 3. shows the resulting relations between symptoms and diseases.

Step 5: Adding the inverse relations. In this steps the inverse relations cure_b, cause_by and is_symptom_of are added to the ontology.

Figure 4. Shows all the explicit relations at the end.

4. Inference Rules

The following inference rules are defined to derive suitable

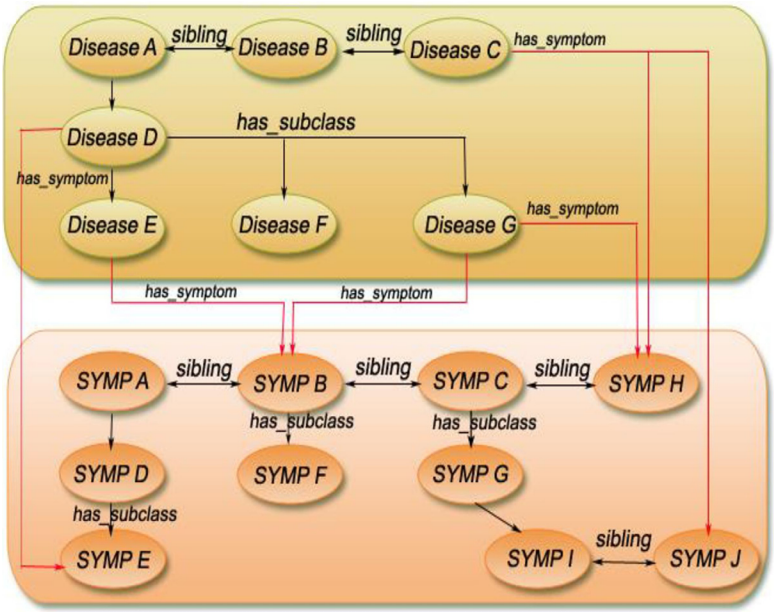

Figure 3. Symptoms and Diseases

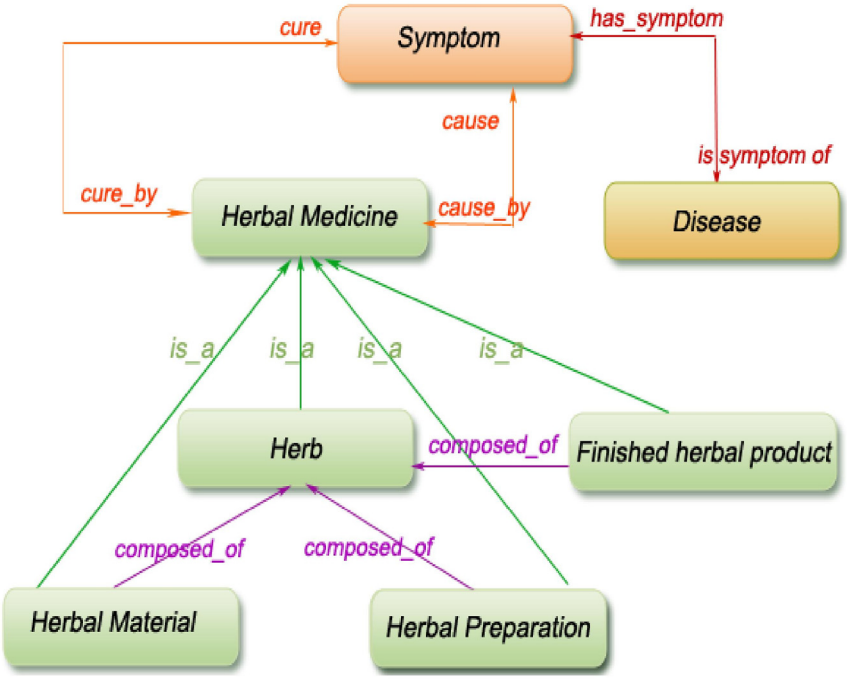

Figure 4. HMO relations

herbs according to the user's casual symptoms and to his chronic diseases; herbal blends can be suggested as a complementary treatment for some diseases; conflicting herbs are detected.

Let:
H_iCureSymptoms = $\{H_iCureS_1, HiCureS_2, ..., H_iCureS_k\}$ denotes the herb H_i cure symptoms.

H_iCauseSymptoms = $\{H_iCauseS_1, HiCauseS_2, ..., H_iCauseS_l\}$ denotes the herb H_i cause symptoms.

***U*Symptoms** = $\{S_1, S_2, ..., S_n\}$ denotes user's casual symptoms.

***U*Diseases** = $\{D_1, D_2, ..., D_m\}$ denotes user's known diseases.

For each disease D_i, we get the list of its symptoms:

D_iSymptoms = $\{D_iS_1, D_iS_2, ..., D_iS_q\}$

***U*DSymptoms** = $\{DS_1, DS_2, ..., DS_p\}$ denotes the union of all user's diseases symptoms lists.

<RULE 1>:
This rule is used for the recommendation of an appropriate herb cure according to the user's casual symptoms and known diseases. The recommended herb must not cause some symptoms that are included in some of the user's diseases symptoms:

An herb H_i is **good** for a user if:

(1) The intersection of H_i cure symptoms list with the user's symptoms list is not empty:

$$H_iCureSymptoms \cap USymptoms \neq \phi$$

(2) The intersection of H_i cause symptoms list with the union of all user's diseases symptoms is empty:

$$H_iCauseSymptoms \cup UDSymptoms == \phi$$

<RULE 2>:
This rule supposes that if an herb H causes symptoms, then every material composed of this herb might cause the same symptoms.

For all triples found in the HMO

(**?HM composed_of ?H**)

(**?H cause ?S**)

Add the new triple:

(?**HM cause ?S**)

<RULE 3>:
This rule is used for the recommendation of an appropriate herbal material cure according to the user's casual symptoms and known diseases. The recommended herbal material must not contain any herb that cause some of user's diseases symptoms.

Apply <Rule 2> to generate herbal materials cause symptoms relations.
An herbal Material HM_i is **good** for a user if:

(1) The intersection of HMi cure symptoms list with the user's symptoms list is not empty:

$$HMiCureSymptoms \cap USymptoms \neq \phi$$

(2) The intersection of HM_i cause symptoms list with the union of all user's diseases symptoms is empty:

$$HMiCauseSymptoms \cup UDSymptoms == \phi$$

<RULE 4>:
This rule suggests herbal blends to be used as a complementary treatment for some diseases.

Apply <Rule 1> as possible to get all adequate herbs

The union of resulting herbs can be mixed

<RULE 5>:
This rule detects conflicting herbs. Two herbs H_1 and H_2 are considered as conflicting, if some caused symptoms by H_1 are contained in the symptoms cured by H_2, or if some caused symptoms by H_2 are contained in the symptoms cured by H_1.

H_1 is in conflict with H_2 if:

$$H_1CauseSymptoms \cap H2CureSymptoms \neq \phi$$

or

$$H_2CauseSymptoms \cup H1CureSymptoms \neq \phi$$

The following section presents three examples of how these rules are applied.

4.1 Examples

Example 1: Let us consider the green tea that is an herb used to cure the following symptoms:

1. Cough

2. Wheezing

3. Chest pain

The green tea also might cause the following symptoms:

1. Insomnia
2. Headache
3. Tremor
4. Vomiting

The relations between green tea and symptoms via cure, cause relationships is shown in Table 1.

The hypertension (HTN) disease has the following symptoms:

1. Blurred vision
2. Drowsiness
3. Tinnitus
4. Nosebleed
5. Headache
6. Flushing
7. Nausea
8. Palpitation
9. Frequent urination
10. Urgency of urination

Herbal class name	Herbal MeSH ontology code http://purl.bioontology.org/ontology/MS	Object Property	Symptom class name	Symptom SYMP ontology code
Green Tea	C465546	**cure**	**cough**	SYMP_0000614
Green Tea	C465546	**cure**	**wheezing**	SYMP_0000604
Green Tea	C465546	**cure**	**chest pain**	SYMP_0000576
Green Tea	C465546	**cause**	**insomnia**	SYMP_0000571
Green Tea	C465546	**cause**	**headache**	SYMP_0000504
Green Tea	C465546	**cause**	**tremor**	SYMP_0000162
Green Tea	C465546	**cause**	**vomiting**	SYMP_0019145

Table 1. Green tea cure and cause relations

Disease class name	DOID ontology code http://purl.obolibrary.org/obo/doid	Object Property	Symptom class name	Symptom SYMP ontology code
Hypertension	DOID_10763	has_symptom	**blurred vision**	SYMP_000012
Hypertension	DOID_10763	has_symptom	**drowsiness**	SYMP_000024
Hypertension	DOID_10763	has_symptom	**tinnitus**	SYMP_0000393
Hypertension	DOID_10763	has_symptom	**nosebleed**	SYMP_0000448
Hypertension	DOID_10763	has_symptom	**headache**	SYMP_0000504
Hypertension	DOID_10763	has_symptom	**flushing**	SYMP_0000511
Hypertension	DOID_10763	has_symptom	**nausea**	SYMP_0000458
Hypertension	DOID_10763	has_symptom	**palpitation**	SYMP_0000530
Hypertension	DOID_10763	has_symptom	**frequent urination**	SYMP_0000563
Hypertension	DOID_10763	has_symptom	**urgency of urination**	SYMP_0000590
Hypertension	DOID_10763	has_symptom	**nocturia**	SYMP_0000564
Hypertension	DOID_10763	has_symptom	**dizziness**	SYMP_0000610
Hypertension	DOID_10763	has_symptom	**breathing difficulty**	SYMP_0019153
Hypertension	DOID_10763	has_symptom	**fatigue**	SYMP_0019177

Table 2. The hypertension symptoms

11. Nocturia

12. Dizziness

13. Breathing difficulty

14. Fatigue

The relations between hypertension and its symptoms are shown in Table 2.

Suppose that a user has a hypertension history, and has the causal symptom "cough". As mentioned previously, the green tea cures the cough symptom, but in the same time, it causes headache that is one symptoms of the hypertension disease. Therefore, <Rule 1> will not recommend the green tea for this user.

Example 2: Let us consider the following symptoms of the "*Mycoplasma pneumoniae pneumonia*" disease:

1. Chest pain

2. Dry cough

3. Chills

4. Sweaty

5. Headache

6. Fever

Applying <Rule 4>, lists the following recommended herbs shown in Table 3.

Herbal class name	Herbal MeSH ontology code http://purl.bioontology.org/ontology/MSH/	Object Property	Symptom class name	Symptom SYMP ontology code
Papaver	D010207	cure	**chest pain**	SYMP_0000576
Papaver	D010207	cure	**dry cough**	SYMP_0000025
Verbascum	D032265	cure	**dry cough**	SYMP_0000025
Bitter orange	D032265	cure	**fever**	SYMP_0000613
Aloe	D000504	cure	**headache**	SYMP_0000504
Peppermint	D036142	cure	**headache**	SYMP_0000504

Table 3. Recommended herbs for the treatment of the Mycoplasma pneumoniae pneumonia

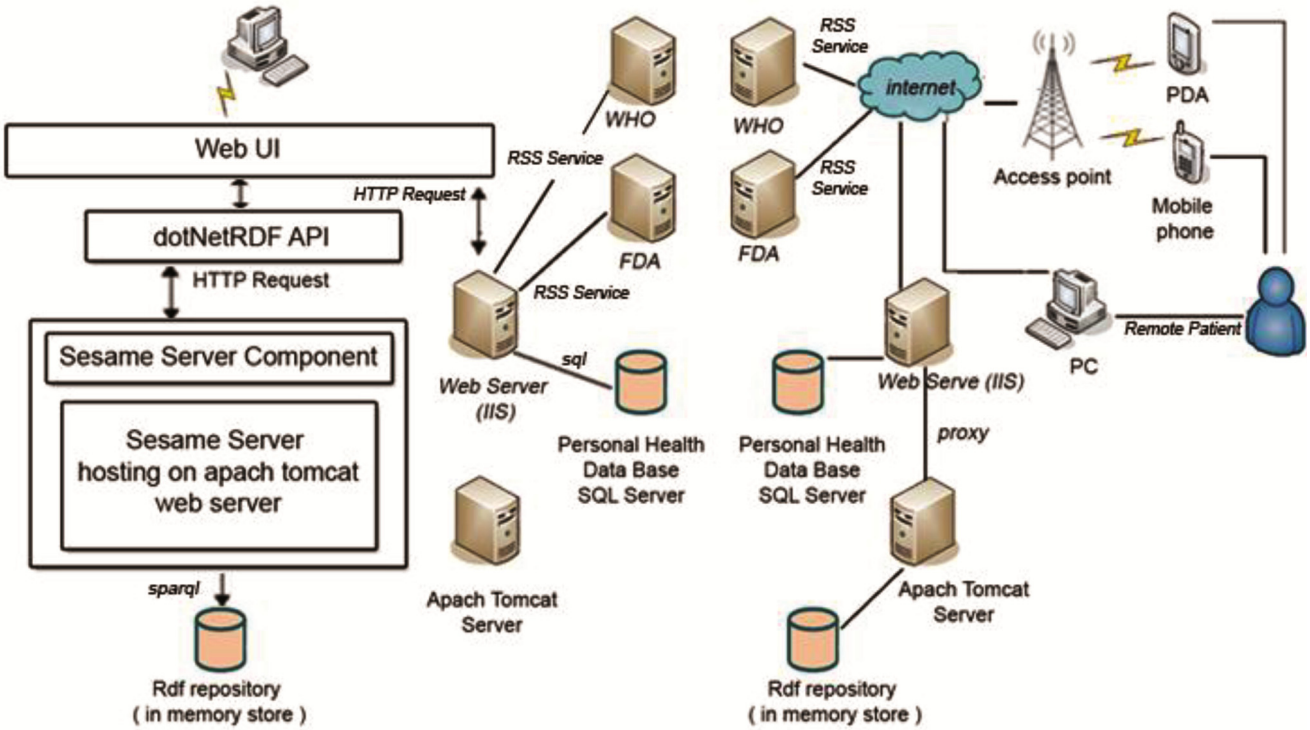

Figure 5. System Architecture

User has the choice to use one or more from the listed herbs. Note that the green tea was not listed even though it cures the chest pain, because it causes headache that is one of the symptoms of this disease.

Example 3: Suppose we want to know the conflicting herbs with the green tea. Applying <Rule 5> gives the aloe and the peppermint as they have common cause and cure symptoms.

5. E-Health Portal

Our herbal medicine ontology can be used in many expert medical applications that aim to infer the adequate herbal treatment according to user's symptoms and diseases.

In addition, this ontology provides information about diseases, symptoms, and the preparation of herbs.

We built an e-health portal as an educational tool where users can easily interact with the system.

5.1 System Architecture

Figure 5. illustrates our system architecture.

The back-end of the system refers to the management and administration of a portal as it allows control over the system from updating to maintenance whereas the front-end refers to the interface that directly interacts with the user.

5.2 Back-End of the E-Health Portal

The back-end has the following components:

• Apache tomcat web server hosts Sesame server.

• The ontology graph, implemented using RDFs, is stored on the Sesame server, where all RDF management operations are executed. SPARQL is used to query the ontology graph.

• Internet Information Services (IIS) to execute asp.net scripts and to render html pages. In addition, it benefits from the RSS service of the WHO (World Health Organization) and the FDA (Food and Drug Administration) servers.

• DBMS SQL Server for storing additional information.

5.3 Front-End of the E-Health Portal

Users need only a browser and an internet connection to access our e-health portal.

A screen shot of the welcome page is shown in Figure 6. Users can browse diseases information (Figure 7), symptoms information (Figure 8), and herbs information (Figure 9).

Figure 10 shows the web form where users can fill their casual symptoms and their chronic diseases; and then get the recommended herbal medicines.

Figure 6. Welcome page

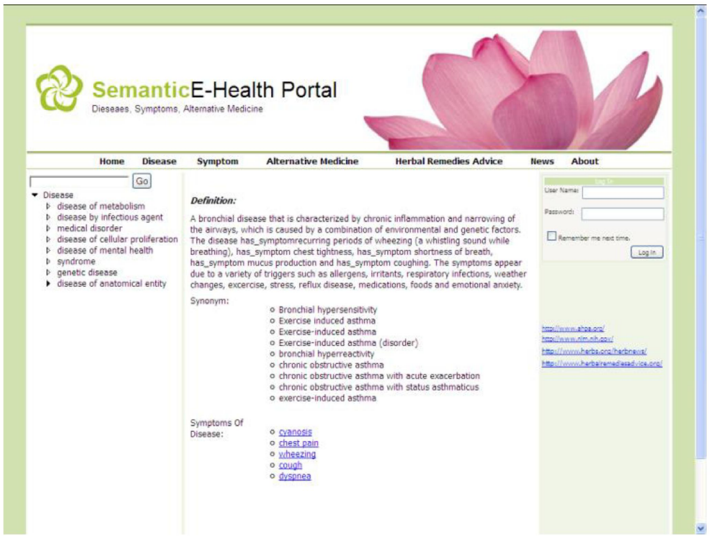

Figure 7. Browsing diseases information

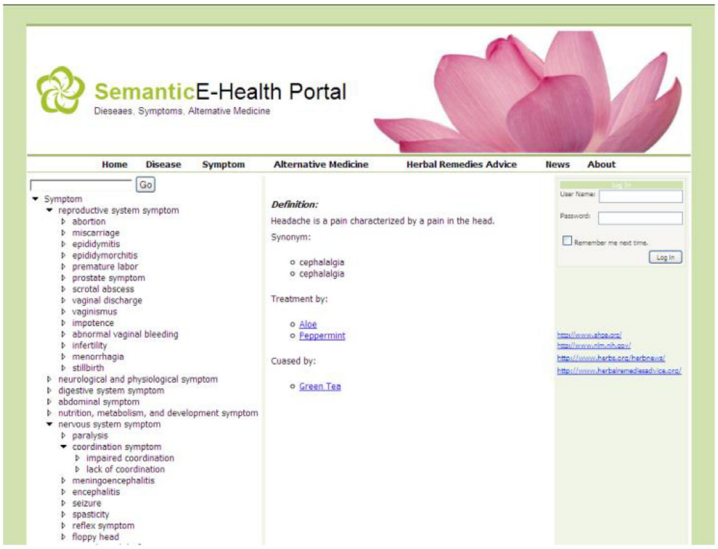

Figure 8. Browsing symptoms information

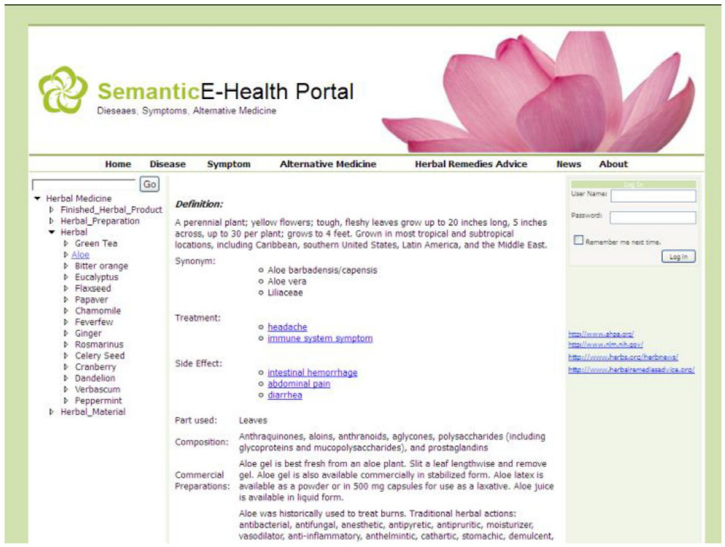

Figure 9. Browsing herbs information

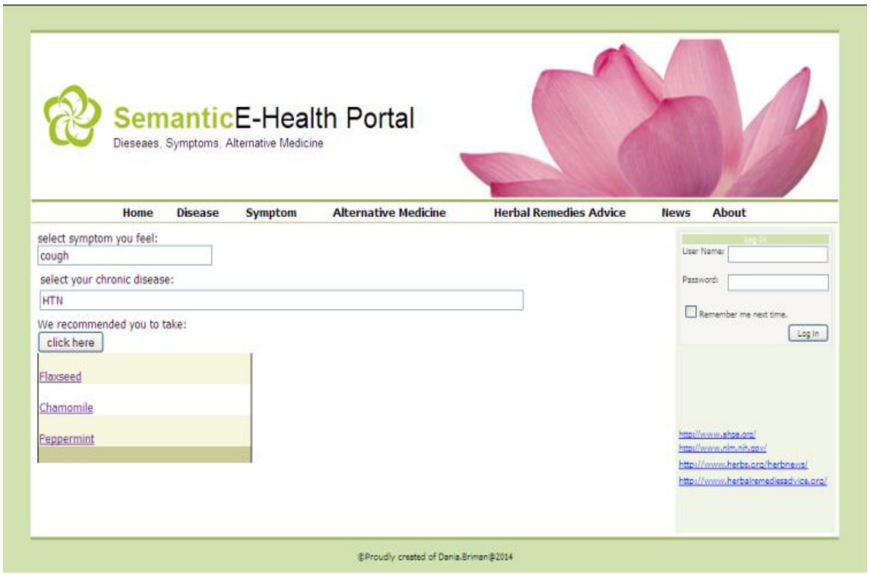

Figure 10. Take an advice of herbal medicine

6. Conclusion

In this work, we elaborated an ontology for the herbal medicine using the world health organization (WHO) categorization. Herbs concepts are imported from the MeSH ontology to promote the interoperability.

Our ontology is aligned with the symptoms ontology SYMP via the cure and the cause relations. Symptoms are aligned with the diseases ontology DOID via the has_symptom relation.

These connections permit to infer the side effects of an herbal medicine according to the side effects of herbs consist in it, to get suggestion of new composition of herbs to treat diseases, and to detect drugs conflicts.

An e-health portal is developed that is used to get recommended herbal medicines, diagnosis of diseases, and suggestion of new composition herbs.

7. Future work

Although we defined conceptual structure of herbal medicine as the WHO categorization, we did not classify the herbs parts (roots, seeds, leaves,…etc) and their usefulness. We are planning to integrate these features in our ontology.

References

[1] Jang, H., Kim, J., Kim, S.-K., Kim, C., Bae, S.-H., Kim, A., Eom, D.-M., Song, M.-Y. (2010). Ontology for Medicinal Materials Based on Traditional Korean Medicine, *Bioinformatics,* 26 (18) 2359-2360.

[2] Arita, M., Suwa, K., Yoshimoto, M., Hirai, A., Kanaya, S. (2009). Ontology Checking and Integration of Crude-Drug and Kampo Information, *In*: *Proceedings of the 2009 2nd International Conference on Biomedical Engineering and Informatics*.

[3] Izumi, S., Takumi Kato, N. M., Varakulsiripunth, R., Kato, Y., Takahashi, K., Shiratori, N. (2010). An Ontology-based e-Health System with Thai Herbs, *Tohoku-Section Joint Convention Record of Institutes of Electrical and Information Engineers*.

[4] Kato, T., Maneerat, N., Varakulsiripunth, R., Takahashi, K. (2009). Ontology-based E-health System with Thai Herb Recommendation, *In*: Proceeding of the 6th International Joint Conference on Computer Science and Software Engineering (JCSSE2009), Thailand.

[5] Atemezing, G., Pavón, J. (2008). An Ontology for African Traditional Medicine, *In*: *International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI'08)*, Salamanca.

[6] Ayimdji, A., Koussoubé, S., Fotso, L. P., Konfé, B. O. (2011). Towards a "Deep" Ontology for Arican Traditional Medicine, *Journal of the Intelligent Information Management,* 3 (6) 244-251.

[7] Oladosu, J. B., Adigun, M., Mbarika, V. W. A. (2012). Towards a Pharmaceutical Ontology for African Traditional Herbs, *In*: Proceedings of the World Congress on Engineering and Computer Science (WCECS 2012), San Francisco.

[8] Chen, H., Mao, Y., Zheng, X., Cui, M., Feng, Y., Deng, S., Yin, A. C., Zhou, Tang, J., Jiang, X., Wu, Z. (2007). Towards Semantic e-Science for Traditional Chinese Medicine, *BMC Bioinformatics,* 8 (3).

[9] Mao, Y., Wu, Z., Tian, W., Jiang, X., Cheung, W. K. (2008). Dynamic sub-ontology evolution for traditional Chinese medicine web ontology, *Journal of Biomedical Informatics,* 41 (5) 790-805.

[10] Cheung, K.-H., Chen, H. (2010). Semantic Web for

data harmonization in Chinese medicine, *Journal of Chinese Medicine,* 5 (2).

[11] Waheed, T., Martinez-Enriquez, A. M., Amjad, S., Muhammad, A. (2013). Development of Upper Domain Ontologies for Knowledge Preservation of Unani Medicines, *Research in Computing Science,* vol. 68.

[12] Team, B. H. I. (2011). Herbal Medicine, 2011. [Online]. Available: http://www.bupa.co.uk/individuals/health-information/directory/h/herbal-medicine. [Accessed 1 6 2017].

[13] Scheuermann, R. H., Ceusters, W., Smith, B. (2009). Toward an Ontological Treatment of Disease and Diagnosis, *Summit on Translational Bioinformatics,* p. 116-120.

[14] Hadzic, M., Chang, E. (2005). Ontology-based Multi-agent Systems Support Human Disease Study and Control, *In*: Proceedings of the 2005 conference on Self-Organization and Autonomic Informatics (I).

[15] Mohammed, O., Benlamri, R., Fong, S. (2012). Building a Diseases Symptoms Ontology for Medical Diagnosis: An Integrative Approach, *In*: International Conference on Future Generation Communication Technology.

[16] Zhang, S., Bodenreider, O. (2005). Alignment of multiple ontologies of anatomy: deriving indirect mappings from direct mappings to a reference, *In*: AMIA Annual Symposium Proceedings.

[17] Homola, M., Serafini, L. (2010). Towards Formal Comparison of Ontology Linking, Mapping and Importing, *In*: Proceedings of the 23rd International Workshop on Description Logics (DL2010).