Development of Upper Domain Ontologies for Knowledge Preservation of Unani Medicines

Talha Waheed[1], Ana M. Martinez-Enriquez[2], Sobia Amjad[3], Aslam Muhammad[4]

[1,3,4] Department of CS & E, UET, Lahore, Pakistan
[2] Department of CS, CINVESTAV, D.F., Mexico

{twaheed, maslam}@uet.edu.pk, sobia.amjad@live.com, ammartin@cinvestav.mx

Abstract. Observing the role of traditional medicines in global healthcare, World Health Organization signifies the need to preserve knowledge of this valuable intellectual property which is being lost or inaccessible, as it is either undocumented or local in context. Unani medicines, a 2500 years old system, has been practiced in Asia, is facing the same situation. Little computerization effort has been done so far earlier in this domain. To preserve the knowledge of Unani medicines, a formal semantic structure is required that is machine readable and reusable. This paper defines a conceptual structure of Unani medicines using upper domain ontology that includes core philosophy, diseases, diagnosis, symptoms, drugs, and treatment of patients. Developed in Protégé, designers have no past experience in ontology development; information collected from books and expert interviews. The proposed ontology serves as a backbone in upcoming knowledge management framework of Unani medicines.

Keywords: Tibb Unani, Unani medicines, traditional medicines, domain ontology, knowledge management framework.

1 Introduction

Traditional medicines have been practiced across the globe since ancient times, the practices continue even today. It is commonly believed that they are cheap and have fewer side effects. Despite of their cultural place, recent research indicates that some herbs have considerable medicinal benefits, but hundreds of traditional medicines still need investigation. World Health Organization (WHO) estimated that 70% of the population in Africa and Asia still depends on traditional medicines to fulfill their health care needs [1] and 30% population of the world have to rely solely on traditional medicines [2]. Global market for traditional medicines was estimated at US $ 114 billion in 2015 in a recent report [3].

WHO recognized its importance in its strategy. To promote the use of traditional medicines for health care in member countries, the organization suggested preserving the indigenous knowledge of traditional medicines [1]. Unfortunately most of the

knowledge is undocumented, and with the deaths of knowledgeable practitioners this great asset is being lost. Whereas, documented knowledge is in local languages, diverse, non-standard, and mostly inaccessible. If the knowledge of their principles, concepts, formulations and practices is preserved and standardized, it can be validated according to modern scientific principles [4] and ultimately it can be included in mainstream healthcare systems.

Unani medicines (locally known as Tibb-e-Unani in sub-continent) is a modified Greco-Arabic system of traditional medicines. In 2500 years of its practices, it absorbed medical traditions of Greek, Arab, Persian, and Indian regions [5]. It is mainly practiced in Pakistan, Afghanistan, India, Bangladesh, Nepal, Srilanka, Iran, Malaysia, Indonesia, Arab region and countries of central Asia. The field of Unani medicines is rich in its documented heritage. There exist thousands of its books on principles and philosophy (Kulliaat), herbal formulations (Nuskha Jaat), and therapies (Mualijaat). The material is written mostly in Arabic, Persian, Urdu, and Indian languages. Unfortunately, the system of Unani Medicines is still not scientifically well studied at larger scale. There are different kind of complexities involved in this work, the material is multi-lingual, geographically and time wise widespread, terminology, and principals are nonstandard, and lack of governmental support are a few.

Before conducting any scientific study, there is a need to preserve and translate knowledge of Unani medicines into international languages so that global access for this information becomes possible. By now there exists a single effort from Indian government to preserve its knowledge [23], but it has its own limitations. Although efforts to preserve knowledge of other traditional medicinal systems of Korea [6], Japan [7], Thailand [8-11], Africa [12-14] and China [15-22] have already been started. Despite the fact that the philosophy and practices of Unani medicines overlaps with other domains of traditional medicines, it is inherently different from these domains with its unique principles, concepts, and formulations that cannot be represented and processed with already developed systems of similar domains. However, their comparison and integration is possible in future.

For compilation, preservation and sharing of Unani medicines knowledge, a web-services based knowledge management framework is required that stores semantically annotated, multilingual, standard, and reusable knowledge into a central web repository. The framework provides collaborative environment between domain experts, researchers, practitioners, and academicians, and acts as an infrastructure for further computerization of Unani Medicines. The knowledge management framework is based on formal semantic structures of ontologies. For the upcoming framework, an ontology for Unani medicines is being proposed in this paper, up to our best knowledge, this is the first ontology in this domain. The ontology mainly contains upper level concepts of Unani medicines, their properties and relationships with other concepts. Our main objective is to provide a platform for preservation, standardization, and validation of Unani system of medicines according to modern scientific principles and ultimately making it able to be included in mainstream healthcare systems. The proposed ontology will be used in the design and development of different semantic-based AI and expert system applications e.g. for diagnostics of diseases, prescription of treatment, etc.

The document organization is as follows: Section 2 presents the work already done using ontologies in similar domains of traditional medicines. Section 3 elaborates seven phases of ontology modeling technique that is employed in the research along with the description of ontology and a usage scenario.

2 Related Work in Similar Domains

A non-exhaustive survey of some ongoing efforts of ontology modeling in other systems of traditional medicines have been presented below, certain practices such as chiropractic, massage, reiki, reflexology, meditation or yoga are not included.

Jang et al. developed ontology of traditional Korean medicines for symptoms, diseases, and treatments [6]. An effort for Kampo ontology, traditional Japanese medicines, is presented by Arita et al. [7]. Multiple efforts to develop ontology of Thai herbal knowledge can also be seen in [8-11].

For the domain of African traditional medicines, Atemezing and Pavon [12] proposed an ontology, which is further enhanced by Ayimdji et al. [13]. Oladosu et al. designed an ontology about African Traditional Herbs [14]. For the domain of Traditional Chinese medicines (TCM), Chen [15] and Mao [16] proposed large scale domain ontology to overcome the problem of 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 [17-22].

Along with above mentioned efforts Traditional Knowledge Digital Library (TKDL) [23] requires special attention. TKDL is an online knowledge repository developed under the supervision of Indian Government, which contains definitions, principles, drug formulations and concepts of Indian traditional medicines. It includes Unani Medicines along with Ayurvedic, Yoga and Siddha. In TKDL the knowledge of traditional medicines available in local language (Urdu, Persian, Arabic, Hindi, etc.) is translated into 5 international languages (English, French, German, Spanish and Japanese). By 2011 around 2.5 Lac drug formulations have been transcribed in TKDL. A classification system, Traditional Knowledge Resource Classification (TKRC) is based on the International Patent Classification (IPC) structure, is specially evolved for this project.

Traditional Knowledge is transcribed in TKRC symbols by using Unicode, XML and Metadata methodology. Samaddar mentioned [24] that TKDL stores knowledge in a text-based database without formal ontologies. So absence of ontologies or similar formal structure reduces its scope. Second limitation of TKDL is that it is unable to offer web-services, which are required for integration with other software applications. Third major issue is that in TKDL keyword based manual queries are allowed, but semantic queries are not possible. So in the present form TKDL does not support semantic web, which requires ontologies to structure data for extendibility, reusability and automatic machine processing. To enable TKDL for semantic web, formal ontologies, web-services and sematic query support is required that serves as a base for Unani medicines computerization.

3 Ontology Modeling for Unani Medicines

Ontologies became popular for organizing and sharing knowledge in the last decade. Whereas "Ontology is a formal, explicit specification of a shared conceptualization" [25]. Ontology should provide descriptions for classes (or things) in the domain of interest, relationship among class members and the attributes that these classes should possess. Huang mentioned that construction of a domain model or ontology is an important part in the development of a knowledge-based system [26]. Depending upon the application of the ontology, different kinds of ontologies exist. Domain ontology is one of the kinds that describe the concepts pertaining to a specific domain.

Developing ontology is a complex task that requires a high degree of analytical and abstract thinking. Therefore, there exist several ontology development methods, each of them with their own objectives depending on the specific needs of application. The method employed in our development is suggested by Noy and McGuiness, it helps beginners in creating their first ontology [28]. In this method, there are following seven phases of research task for the construction of ontology:

3.1 Determine the Domain and Scope of the Ontology

In the first phase of modeling, domain and scope of the ontology have been clearly defined. Noy and McGuinness raises some basic questions in their methodology [28] that clarifies the objectives of the ontology and limits its scope. So domain of our ontology is Unani medicines, and it is proposed for preservation and standardization of knowledge. At present, it only covers upper level domain knowledge of Unani medicines that includes core principles, symptoms, diagnoses, patient, treatment and, disease. It helps researchers, academicians and Unani medicines practitioners (locally known as hakeem) to share their common understanding of the domain. For software developers, it also provides semantic structure and knowledge base thru web-services interface for writing different computing applications.

3.2 Consider Reusing Existing Ontologies (if any)

Up to our best knowledge, there exists no relevant ontology that can be reused in our case so proposed Unani medicines ontology is initially being developed from scratch. However, in future it can be compared and linked with existing ontologies of other traditional medicines domain, so integration and reuse of their software applications and data become possible.

3.3 Enumerate Important Terms in the Ontology

This is the phase where important terms, concepts and properties of the domain ontology are defined that required explanations. Expert interviews, literature reading, observations, and questionnaires helps in listing these terms. For enumerating the terms, explicit knowledge of domain is captured from Unani medicines source books

and written material and tacit knowledge is gathered by interviewing domain experts and local practitioners. Outcome of this stage for our proposed ontology resulted core terms as Family History, Drugs, Diseases, Examination, Signs and Symptoms, Element, Organs, Temperaments, Humours, Pneumas, Limitations, etc.

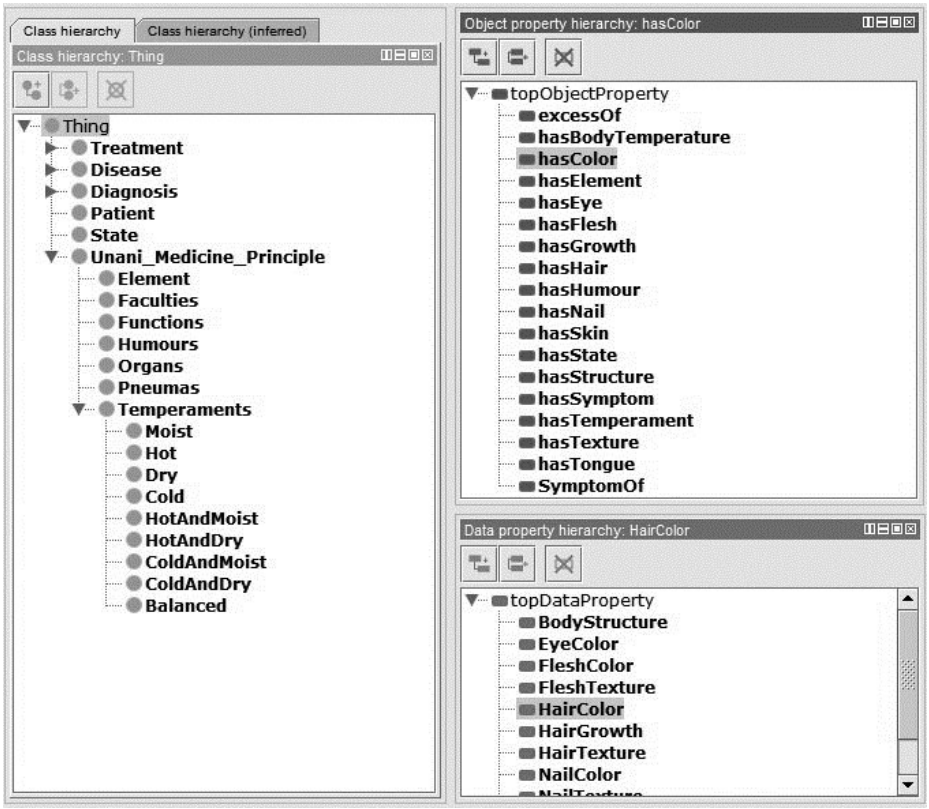

Fig. 1. Class Hierarchy, Object and Data properties of proposed ontology

3.4 Define Class and Class Hierarchy

In the fourth phase, classes (a concept in the domain) and their super and sub-class hierarchy has been defined. Gruber mentioned that there are several possible approaches in developing a class hierarchy [25]. Top-Down approach is employed in our research in which hierarchal structure and top level concepts of the ontology are identified as super classes. The design of class hierarchy and level of details depends on the possible uses of the ontology that is required for the application.

For our proposed ontology classes of Unani medicines and their hierarchy (see Fig 1) are defined using Protégé [27]. All classes in the hierarchy are subclasses of Thing, as per convention of Protégé. So, six main classes of ontology Treatment, Disease, Diagnosis, Patient, State and Unani_Medicine_Principle are derived from Thing, each of them with their own hierarchy of subclasses. It has also been verified from domain

experts that top level classes cover all major terms of Unani medicines that have been found in phase 3.

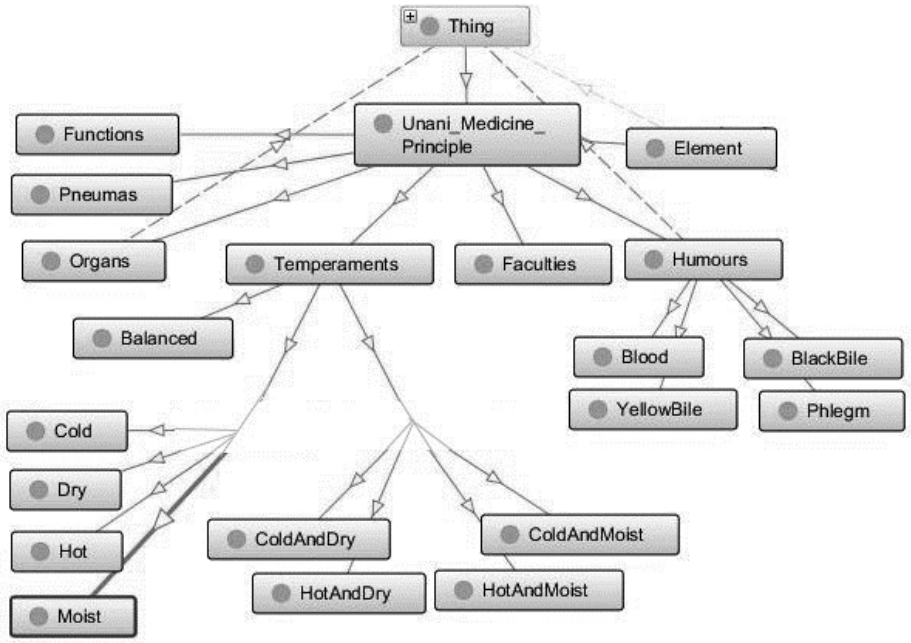

Fig. 2. Ontology Graph of Unani_Medicines_Principle in Protégé

The **Unani_Medicine_Principle** class describes all the core concepts and philosophy of Unani Medicines. It distinguishes Unani medicines from other domains of traditional medicines like Ayurveda and Chinese medicines, each of them with their own core concepts and principles.

After these 6 main classes, sub-classes of each of them have been defined. Only subclasses of Unani_Medicine_Principles need further elaboration. Unani medicines is a wholistic approach towards the whole human body and divide it into seven core components, known as Umoor-e-Tabiya [29] in Urdu language. These are Element (Arkaan), Temperaments (Mizaj), Humours (Akhlaat), Organs (Aa'za), Faculties (Quwa), Functions (Afa'al) and Pneumas (Arwaah). (see Fig. 2). Some of them are further elaborated in their subclasses.

3.5 Define Class Properties (or Slots)

Classes (or concepts) and class hierarchy alone does not preserve all the required semantics of the domain. Every instance of a class has some associated properties (or attributes). Some of the properties are data properties and some are object properties.

The **Data properties** may be simple or complex. Simple contains primitive data of concepts that comprises of strings, numbers, etc. Whereas complex properties contains other objects (See Fig. 1, lower right window for data properties.)

The **Object properties** are defined to relate two classes (or concepts) and hence their objects (two classes may be same or different). In ontologies, object properties may exist independently or may be related to one or more class. Following is a short description of object properties which are defined for our ontology (See Fig. 1, upper right window for object properties.)

excessOf relates Patient with Humour, it shows the excess of any of four Humour values: Blood, Phlegm, YellowBile or BlackBile, i.e. excess may cause specific Disease related to that Humour.

hasBodyTemperature Patient with its Symptom for having body temperature, increased, decreased, or normal.

hasColor relates Patient with Symptom of Eye, Hair, Skin, or Tongue color, that helps in identification of Temperament or Disease, and ultimately in Diagnosis.

hasElement relates any of Temperament value with related value of Element according to Unani medicines principle.

hasGrowth relates Patient with Symptom of abnormal or normal Hair growth, that leads to Diagnosis process.

hasHumour provides any of four Humour value of Patient that is in excess.

hasState relates any of four Element with relevant value from four State.

hasStructure relates Patient with broad or short Body Structure as Symptom.

hasSymptoms relates Patient Disease with any associated Symptom.

hasTemperament links concept of Temperament with concepts of Patients, Humours or Organs.

hasTexture relates Patient with Symptom of Abnormal Hair or Nail texture, providing clue in Diagnosis of Diseases.

SymptomOf relates Symptoms with Disease; it is inverse of hasSymptom property.

Similarly object properties of **hasTongue**, **hasSkin**, **hasNail**, **hasHair**, **hasEye** and **hasFlesh** relates Patient to his physical attributes.

3.6 Define the Facets (or Constraints) of the Properties

In this phase facets (constraints and restrictions) of the properties, have been applied. Facets limit the set of possible values for any property. Commonly applied facets are cardinality and Type of Value. Currently only one restriction in the ontology is enforced that patient is a person that has at least one disease associated with it (otherwise the person is healthy, not a patient).

3.7 Create Instances

Once all the classes, subclasses, object and data properties, facets have been defined, individuals of classes are created. Individuals (like objects in object oriented

paradigm) are specific instances of classes. In proposed ontology a lot of individuals have been created (See left side window in Fig. 3).

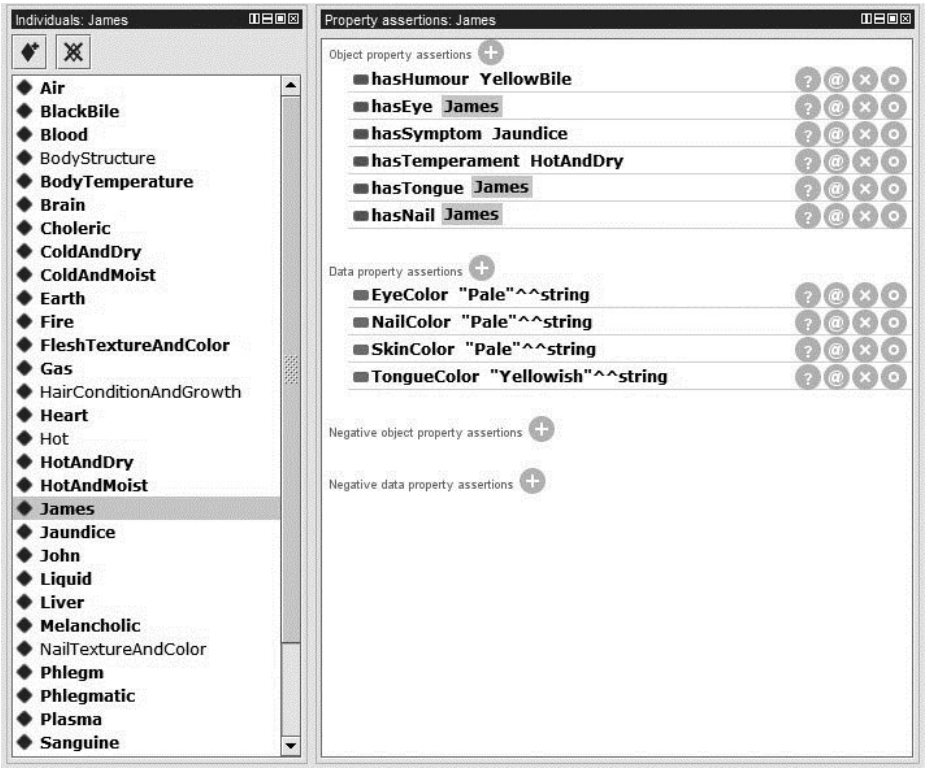

Fig. 3. An individual of a class at left its data and object properties in lower right

A real world scenario is presented in Fig. 3 that elaborates how our proposed ontology can be used in a clinical decision support system that assists Unani practitioners.

For instance, whenever a patient arrived, naming James, an instance of class Patient is created for him and practitioner using the system input values of data properties of James; TongueColor is Yellowish, NailColor is Pale, EyeColor is Pale and SkinColor is Pale too. There exists a rule in the system, which infers his Humour using the given data as YellowBile.

```
RULESTART “YellowbileHumour”
        IF (TongueColor is Yellowish AND
            NailColor is Pale AND
            EyeColor is Pale AND
            SkinColor is Pale)
        THEN Humour is YellowBile
ENDRULE
```

Concepts of Humor of Patient and YellowBile are linked (by hasHumor object property), whereas Temperament of YellowBile is already semantically linked in our ontology to HotAndDry (by object property hasTemperament) and by applying reasoning system suggests that James has chances of Jaundice (object property of hasSymptom is semantically linked in ontology with Jaundice). So the ontology links semantically related concepts and helped in semantic searching.

In the same way, by using the proposed ontology, decision support system can infer new facts from family history and signs and symptoms of James, and helps in prescription of drugs for the treatment of Jaundice.

4 Conclusion and Future Work

We proposed upper domain ontology for knowledge preservation of Unani medicines, an Asian system of traditional medicines. It is the first ever ontology for this field. The ontology currently covers the core principles of Unani medicines, patient, diagnosis, symptoms, disease, and treatment. The ontology organizes common understanding for information of the domain both for human and for software agents; it serve as the base semantic structure for linking concepts of Unani medicines with each other, by restricting the types and values of each concept and helps in semantic searching and navigation. All of these above mentioned features are previously not possible in text-based databases, like traditional knowledge digital library, that have no built-in conceptual structure and offer only keyword based search. In upcoming work, ontology will be further expanded to broaden its depth and breadth and validated by employing it in expert systems, clinical decision support systems and different AI and machine learning applications.

References

1. WHO: WHO traditional medicine strategy 2002−2005. WHO, Geneva (2002)
2. Patwardhan, B.: Traditional Medicine: Modern Approach for Affordable Global Health. WHO-Commission on Intellectual Property Rights Innovation and Public Health (CIPIH), Study Nine on TM, WHO, Geneva. (2005)
3. Global Industry Analyst: Alternative Medicine: A Global Outlook. Report published by Global Industry Analyst, Inc. San Hose (2012)
4. Tinnaluck, Y.: Modern science and native knowledge: collaborative process that opens new perspective for PCST. J. Quark No. 32: Apr−Jun 2004, Spain (2004).
5. Magnor, L. N.: A History of Medicine. 2nd Ed., Taylor and Francis, USA (2005).
6. Jang, H., Kim, J., Kim, S.-K., Kim, C., Bae, S.-H., Kim, A., Eum, D.-M., Song, M.-Y.: Ontology for Medicinal Materials Based on Traditional Korean Medicine. Bioinformatics 26(18), 2359−2360 (2010)
7. Arita, M., Suwa, K., Yoshimoto, M., Hirai, A., Kanaya, S.: Ontology Checking and Integration of Crude-Drug and Kampo Information. 2nd Int. Conf. on BMEI, Tianjin, pp 1−4 (2009)
8. Nantiruj, T., Maneerat, N., Varakulsiripunth, R., Izumi, S., Shiratori, N., Kato, T., Kato, Y. and Takahashi, K.: An e-Health Advice System with Thai Herb and an Ontology, In

Proceeding of the 3rd International Symposium on Biomedical Engineering (ISBME 2008), pp.315−319 Thailand (2008)

9. Kato T., Maneerat N., Varakulsiripunth R., Kato Y., Takahashi K.: Ontology-based E-health System with Thai Herb Recommendation. In Proceeding of the 6th International Joint Conference on Computer Science and Software Engineering (JCSSE2009), pp.172−177, Thailand (2009)
10. Kato T., Maneerat N., Varakulsiripunth, R., Izumi, S., Takahashi, H., Suganuma, T., Takahashi, K., Kato, Y., Shiratori, N.: Provision of Thai Herbal Recommendation Based on an Ontology. In 3rd Int. Conf. on Human System Interaction (HSI2010), pp.217-222, Poland (2010)
11. Izumi, S., Kuriyama, D., Itabashi, G., Togashi, A., Kato, Y., Takahashi, K.: An Ontology-based Advice System for Health and Exercise. In Proceedings of the 10th International Conference on Internet and Multimedia Systems and Applications (IMSA2006) pp.95−100 (2006)
12. Atemezing, G., Pavon, J.: An Ontology for African Traditional Medicine. International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI'08): In Series: Advances in Intelligent and Soft Computing, Salamanca, Vol. 50, pp. 329−337 (2008)
13. Ayimdji, A., Koussoubé, S., Fotso, L.P., Konfé, B.O.: Towards a "Deep" Ontology for African Traditional Medicine. In J. of the Intelligent Information Management, pp.244−251 (2011)
14. Oladosu, J.B., Adigun M.O., Mbarika V.: Towards a Pharmaceutical Ontology for African Traditional Herbs. In Proceedings of the World Congress on Engineering and Computer Science (WCECS 2012), Vol. I, San Francisco (2012)
15. Chen, H., Mao, Y., Zheng, X., Cui, M., Feng, Y., Deng, S., Yin, A., Zhou, C., Tang, J., Jiang, X., Wu, Z.: Towards Semantic e-Science for Traditional Chinese Medicine, BMC Bioinformatics, Vol.8(3) (2007)
16. Mao, Y., Wu, Z., Tian, W., Jiang, X., Cheung, W.K.: Dynamic sub-ontology evolution for traditional Chinese medicine web ontology. J. Biomed. Inform., 41(5), pp.790−805 (2008)
17. Cheung K.H., Chen H.: Semantic Web for data harmonization in Chinese medicine. In J. of Chinese medicine, 5(2) (2010)Jokiniemi, J.: Ontologies and Computational Methods for Traditional Chinese Medicine, Master's Thesis, School of Science & Technology, Aalto University, Finland. (2010)
19. Zhao J.: Publishing Chinese medicine knowledge as Linked Data on the Web. In J. of Chinese Medicine, 5(27) (2010)
20. Qi, X., Meng, C., Cungen, C., Baoyan, L., Changlin, L., Hongguan, J.: Establishment of the TCM Meta Conceptual Model Based on Domain Ontology. In J. of World Science and Technology Modernization of Traditional Chinese Medicine, Vol.11(4) pp.621-625 (2009)
21. Yu, T.: Ontology Engineering for Chinese Medicine - Connecting eastern and western medicine, Technical Report of CCNT DartGrid Group, Zhejiang University, Hangzhou, Zhejiang, China (2008)
22. Traditional Knowledge Digital Library, http://www.tkdl.res.in/
23. Samaddar, S.G., Chaudhary, B.D: Development of a Framework for Traditional Knowledge Digital Library (TKDL-S) Semantic Web Portal for Santal Medicinal System. J. of Science and Culture, Vol. 76 (11–12) pp. 544−551 Kolkata India, Nov-Dec (2010)
24. Gruber, T.R.: Toward principles for the design of ontologies used for knowledge sharing. In International J. of Human-Computer Studies - Special issue: the role of formal ontology in the information technology Vol. 43 (5−6) pp. 907−928 (1995)

25. Huang, M.J., Chen, M.Y.: Integrated design of the intelligent web-based Chinese Medical Diagnostic System (CMDS) – Systematic development for digestive health. Expert Systems with Applications, Vol. 32(2) pp.658−673 (2007)
26. Protégé Ontology Editor and Knowledge-base framework, http://protege.stanford.edu/
27. Noy, N.F., McGuiness, D.L.: Ontology Development 101: A Guide to Creating Your First Ontolotgy. Technical Report KSL−01−05, Stanford Knowledge System Laboratory (2001)
28. Ahmad S.I.: Introduction to Al Umur Al Tabiya - Principles of Human Physiology in Tibb. Saini Printer, Pahari Dhiraj, New Delhi (1980)