Original Article

TJPS
The Thai Journal of Pharmaceutical Sciences
39 (3), July-September 2015: 102-109

Development of Thai herbal medicine knowledge base using ontology technique

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Abstract

This study proposes a method for developing a knowledge base of Thai herbal medicine by using ontology techniques and developing its application as a semantic search system. Since knowledge of Thai herbal medicine is often presented in flat knowledge and lacking in taxonomies, clear understanding of the whole picture of illness and treatment with Thai medicinal plants can hardly be attained. To address this problem ontology has been introduced to create the explicit state of Thai herbal medicine knowledge. Ontology techniques help identifies key concepts and relationships among the concepts in the domain knowledge. The resulting application, Thai Herbal Medicine Ontology (THMO), covers concepts derived from Thai herbal medicine as well as folk medicine. THMO consists of 10 major concepts: Formulation, Finished Product Form, Herb Material, Clinical Warning, Taste, Tri-That, Health Problem and Use Method. The validity of THMO was evaluated by eight professional experts— two ontology engineering specialists and six traditional doctors. The experts' opinions in general strongly agreed with THMO regarding concept identification, relationship identification, correctness and reusability. As a semantic search THMO application was found to improve the efficiency of information query by excluding non-relevant information.

Key Words: Herbal medicine, Ontology development, Semantic search

Introduction

Thai Traditional Medicine (TTM) is an array of indigenous medical practice which has long been used in Thailand. Since 2012, the government has set up policy and strategies aimed to make the science of Thai traditional medicine acceptable among people [1]. Consequently, TTM including Thai Herbal Medicine is widely practiced nationally. Thai Herbal Medicine knowledge can be found in several existing official textbooks including *Phaetsart Songkroh: Medical wisdom and national literacy heritage, Explanation of Tamra Phra Osot Phra Narai, Textbook of Medicinal Properties*, etc. The main principle of TTM includes the study of cause of illness, body elements, diagnosis, treatment method, herbal medicine and taste as quality of medicine [2].

Although TTM knowledge has been well documented in textbooks and traditional manuscripts, it is often presented in flat knowledge form, i.e., lack of depth in taxonomies and hierarchy [3], and not well-organized.

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Received: 25 May 2015
Revised: 7 July 2015
Accepted: 14 July 2015

Academic Editor: Wanchai De-Eknamkul

The practice and functions in the textbooks are only used as frame of reference. They typically involve practice but frequently do not dictate the theoretical framework [4]. In Herbal Medicine, the relationships between herbs or herbal formulations with treatments are still unclear. The lack of taxonomic model provides only glimpse of total picture of illness that does not provide clear understanding in treatment and treatment formulation [4]. In terms of knowledge management, Thai Herbal Medicine knowledge should deploy a more well-organized form regarding the next generation of information requirement [5]. This will enable TTM knowledge to be reusable/sharable and permits interoperation between knowledge domains.

Ontology is a knowledge model that represents a set of concepts within a domain and the relationships among these concepts [6]. Ontology helps in knowledge organization and management in both content and information staging as well as in content deployment [7]. This study uses ontology for the conceptualization process of domain knowledge focused mainly on the philosophy and practice of Thai herbal medicine. It provides a conceptual model of scientific management of Traditional medicine information. The result of well-constructed ontology helps to reveal relationships between treatment and healing materials which were often not explicitly stated previously. The developed ontologies can also be used for integration and interoperation with others clinical ontologies. This article also explains the TTM ontology application in a semantic search system for the treatment of illness with herbal medicine. Using this application, the users can conduct concept-based search (in addition to a keyword search) and express their information needs based on the ontology [7]. Ontology-based semantic search aims to enhance efficiency of searching process.

This study aims to develop a systematic knowledge management framework of Thai Herbal Medicine according to Thai Traditional Medicine theory by using ontology and to develop its application as a semantic search system, in order to provide an effective herbal medicine search for treatment of illness. The system expected to improve efficiency of search results by provide more relevant results.

System Framework

The system framework as shown in **Figure 1** consists of module of knowledge base, ontology, database and user interface. The ontology technology was used in creating conceptual knowledge for Thai herbal medicine. The herb database which was originally created by using MS Access was exported to MySQL database servers. In constructing the knowledge base, the database data was integrated with the ontology to create the knowledge base in the RDF (Resource Description Framework) format by using Ontology Application Management (OAM) framework. RDF is a standard model for data interchange. It facilitates data merging between different schemas. In this study, it facilitated the ontology schema and instance of data store to be stored in OAM. In addition, the OAM semantic search application template is adopted in order to create the search system and user interface. After implementing all these steps, user can perform querying process on top of the provided SPARQL query facility. This article focuses on the scope of domain knowledge necessary in answering the relevant queries in TTM.

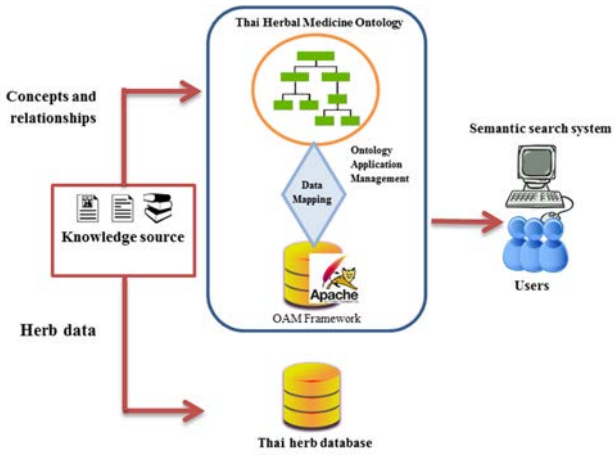

Figure 1 System framework

Materials and Methods

Material: Hozo ontology editor, developed by the Institute of Scientific and Industrial Research, Osaka University, Japan [8]; Ontology Application Management (OAM), developed by the Language and Semantic Technology Laboratory, National Electronics and Computer Technology Center (NECTEC) [9]; MySQL 5.0; and Microsoft access 2010.

Methods: The construction of Thai Herbal Medicine Ontology (THMO) used an ontology editing tool, Hozo. Hozo is an environment for building ontology. The features of Hozo support the role representation and visualization of ontology schema based on knowledge domain [8]. Ontology can be exported from Hozo to the OWL (Web Ontology Language) format, which is the standard language for creating ontology. The steps of development process of this study are shown in **Table 1** and are described as follows.

Table 1 THMO Building process and application development

Step	Process
1	Extraction of the relevant information in herbal medicine
2	Identification of concepts/ classes
3	Definition of classes' hierarchy
4	Definition of data properties and object properties
5	Preparing Thai herbal medicine database
6	Mapping THMO with the Thai herbal medicine database and creating the knowledge base

Step 1 Extraction of the relevant information in the herbal medicine: This step defines the scope of knowledge in Thai herbal medicine and information

collection. Concepts of herb were extracted according to those found in *Tamra Pramuan Lak Phesatchakam* (ตำราประมวลหลักเภสัชกรรม) [10] and *Wetchasuksa Phaet Thayasat Sangkhep* (เวชศึกษา แพทย์ศาสตร์สังเขป)*: Manual for Student of Traditional Medicine by Phraya Phit sanuprasatwet* [11]. The concepts of illness/health problem and disease in TTM were extracted from *Phaetsart Songkroh: Medical Wisdom and National Literary Heritage* [12]. The book is one of the key indigenous textbooks of Thai medicine containing several Kamphi (คัมภีร์) or traditional medicine manuscripts which officially endorsed by the Ministry of Public Health and widely used as reference source in Thai traditional medicine. It contains theories of Thai traditional medicine and pharmacy such as diagnosis, treatment method, cause of illness, herbal medicine etc.

Step 2 Identification of concepts/classes: Concepts or classes of domain knowledge were enumerated for inclusion in THMO in this step. The knowledge domain in this study covers information of Herbal medicine-Herbs, Taste, Tri-That, Formulation, Indication, Preparation, Use Method and Clinical Warning. All the defined concepts are used in the knowledge base and linked to the relevant information in answering the user queries.

Step 3 Definition of classes' hierarchy: This step is a process of assigning the superclass/ subclass relationships of classes represented in hierarchical form, i.e. IS-A relationship. For example, 'Precaution' and 'Contra-diction' concepts are defined as two subclasses of 'Clinical warning type' concept.

Step 4 Definition of data properties and object properties: In this step, the properties of the classes were assigned. There are two types of properties to be defined: data properties and object properties. The data type properties are used to describe the value type of the classes such as string, boolean, number, etc. For example, the data properties of the 'common name' and 'trade name' of the Formulation class (as in the name or trade name of the formulation) are string. The 'name' is a class with value type String. The object properties were defined to describe the association of two related concepts/classes in ontology. It provides more information to describe the attached class. For example, the 'Formulation' concept has five object properties: has_indication, has_ADR, has_dosage_form, has_plant_ingredient, and has_clinical_warning. These properties are used to relate the 'Formulation' concept to the 'Indicaiton'. 'Adverse reaction', 'Finished product form', 'Plant ingredient' and 'Clinical Warning' concepts respectively. All the properties provide more information about the attached class which is the Formulation.

Step 5 preparing the database on Thai herbal medicine: In this step, the ontology schema was exported from Hozo into the OWL representation language. The Web Ontology Language (OWL) [13] is used as a representation language of THMO. In this study, the Thai herbal medicine database originally created in MS Access database software was exported to MySQL database server in order to prepare data for the data mapping in the next step.

Step 6 Mapping THMO with the Thai herbal medicine database and creating the knowledge base: The data mapping process in this step used the Ontology Application Management (OAM) software tool [9]. With support of OAM, mapping between the OWL ontology and the database schema can be performed using a graphical user interface. After the database-ontology mapping process, the tool allows creation of the knowledge base in RDF format [14]. In order to generate applications of THMO, the OAM semantic search application template was used in developing a concept-based search system for Thai herbal medicine, which allows user to browse and search for the relevant information.

Results and Discussion

The Thai Herbal Medicine Ontology (THMO) contains 323 concepts. List of some key concepts in THMO is shown in **Table 2** and described as follows.

Table 2 Important concepts in THMO

Concepts	Description
Herb Material	Medicinal material in formulation, include plant material, animal material and mineral material
Taste	A property of herb material which can refer to the treatment properties
Tri-That	A classification of body elements according to Thai Traditional Medicine theory, contain Vata, Pitta and Kapha.
Formulation	A combination of herbal material in treatment of health problems
Use method	Methods of administration the herbal formulation in to the body according to the administration route
Health problem	List of health problems according to body system which include health problem in Thai Traditional Medicine Textbooks
Indication	Advice of the formulation for treatment of illness
Adverse reaction	Adverse event related to herbs or formulations
Finished Product Form	The form or dosage form of products made from herbs
Clinical warning	Warning information of herbs or formulations

THMO consists of 10 major classes: Formulation, Indication, Adverse Reaction, Finished Product Form, Herb Material, Clinical Warning, Taste, Tri-That, Health Problem, and Use Method.

1) The Herb material class represents the materials use for the medicinal purpose defined in the definition according to the Traditional pharmacy material definition in the official original medical book, *Tamra Pramuan Lak Phesatchakam* (ตำราประมวลหลักเภสัชกรรม) [10] *and Wetchasuksa, phaetthayasat sangkhep* (เวชศึกษา แพทย์ศาสตร์สังเขป)*: Manual for student of Thai traditional medicine* [11]. The main component of the Herb material is the Plant material. It represents information of plants under heading include plant botanical name, synonym, taste of plant, part of plant use as medicine and clinical warning of plant. Other types of materials used in Thai pharmacy are animal materials and mineral materials, were also defined under this class as shown in **Figure 2**.

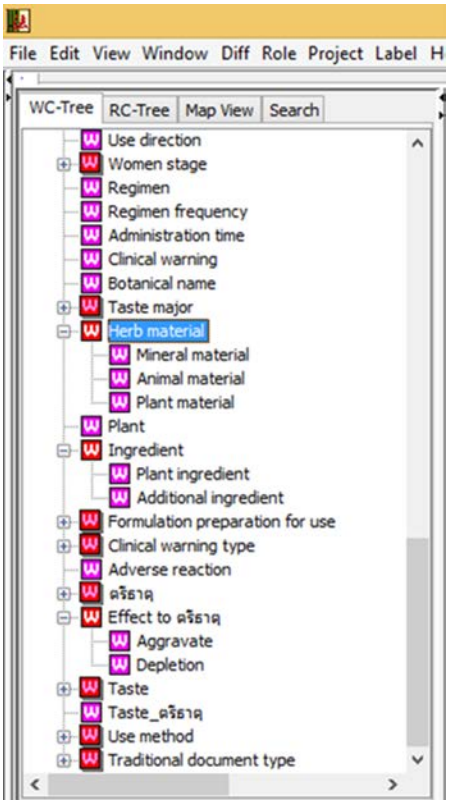

Figure 2 A Herb material class

2) The Taste class was defined according to the principle of Thai traditional pharmacy principle [11] in which tastes of herb in traditional pharmacy are not merely sensation on the tongue but indicate the properties of medicine which practitioners must adhere. When a traditional doctor prescribes herbs or makes herbal remedies for their patients, taste is one of factors which they usually consider. Here tastes are classified according to two principles. The first classified them into nine medicinal tastes: sour, sweet, astringent, bitter, salty, spicy, oily, mao buea (เมาเบื่อ) and, mild and fragrant (หอมเย็น). The class hierarchy of taste is shown in **Figure 3**. The second classified them into three sensational properties of herbs: hot, cold and su-khum.

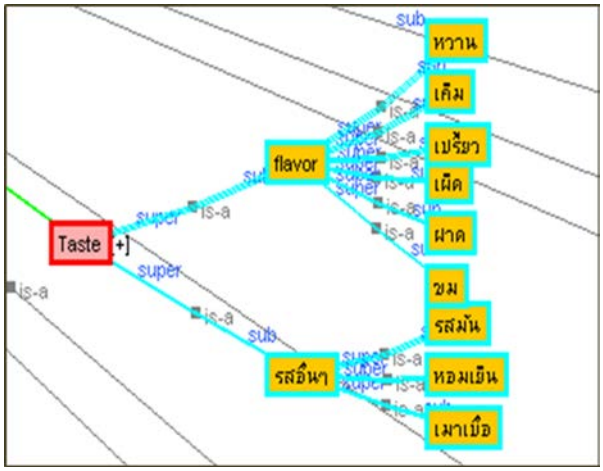

Figure 3 The Taste hierarchy

3) The Tri-That (ตรีธาตุ) *class* represents the concept of three body elements namely; Vata, Pitta and Kapha. The Tri-That theory is one of foremost classification concepts of body elements in Thai traditional medical text, influenced by Ayurveda [3]. When the abnormalities of those elements occur, these cause malfunctions of the body. Illnesses or health problem could occur. The relation between Taste and Tri-That were represented as 'aggravation' and 'depletion' properties.

4) The Formulation class is the main class in THMO. It aimed to represent necessary information available for users, including information of ingredients, indication, regimen, clinical warning, adverse reaction and dosage form of the herbal formulation. This class serves as a connecting class of important concepts in THMO. The relationships among the classes obtained through the object properties are shown in **Figure 4**.

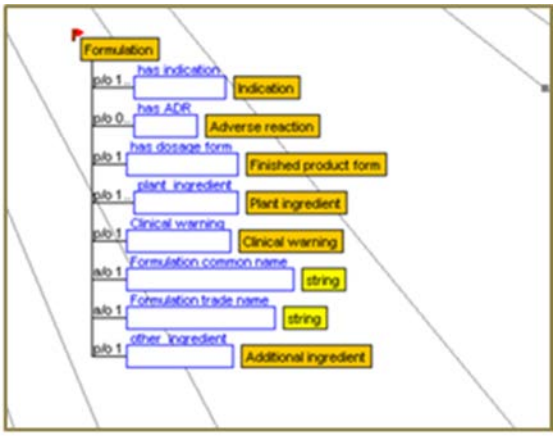

Figure 4 The Formulation class and part of relationships

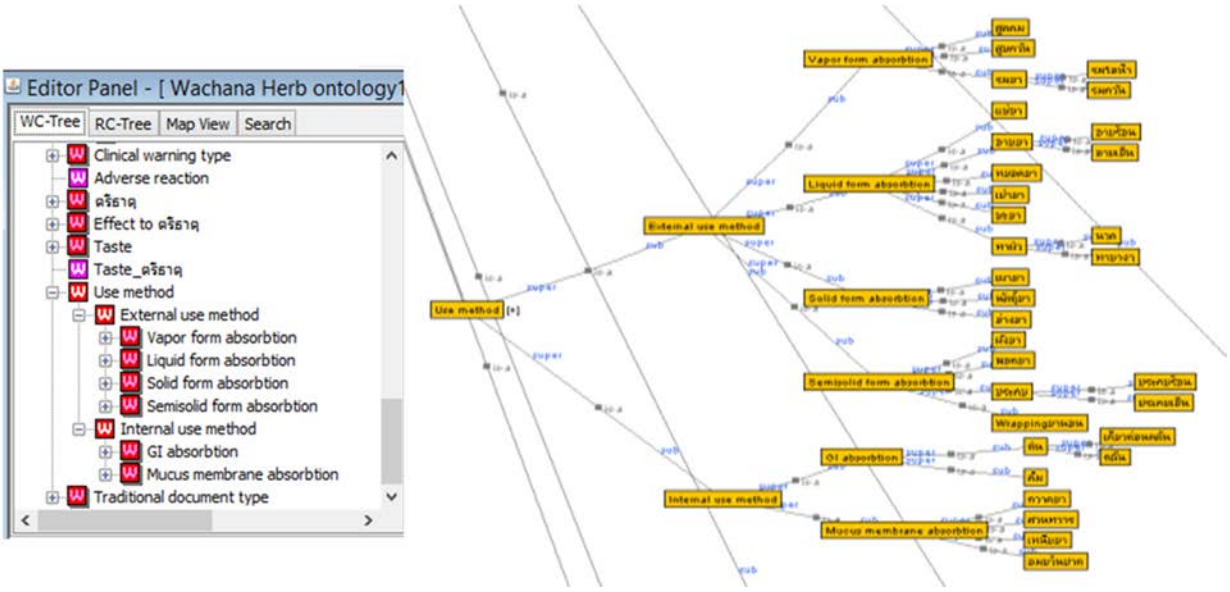

Figure 5 The Use method class

5) The Use method class aims to conceptualize the method of administration of herbs/herb formulations based on the routes of administration to the body, which can cover all practices in traditional pharmacy and folk medicine. According to Thai traditional pharmacy textbook, there are 23 methods of using herbal medicine [10]. Yet, there are extraordinary methods-for example, roasting, sudation, body wrapping- they have been practiced by folk doctors and people in communities around the country but not recorded in the above textbooks. These are also included under this class. These use methods were conceptualized from a survey and interview with traditional folk practioners conducted by the Chao Phya Abhaibhubejhr Hospital Foundation. The taxonomy of the use method is shown in **Figure 5**.

6) The Health problem class represents groups of health problems in both Thai traditional medicine and conventional medicine aspects according the body system. THMO has classified Thai traditional diseases such as "Ka-sai" in the systematic symptom and disease sub-class. "Ka-sai' is a disease unique to Thai traditional context, affecting has several organs and causing a wide range of symptoms. Additionally, Fever, Element deficiency (That Phi Kan, ธาตุพิการ) and Rok Lom (โรคลม) are the common illness frequently mentioned in several textbooks and are conceptualized in this ontology. The relationship of health problem and formulation is connected by means of the indication concept *via* the relationship of *hasHealth Problem* (**Figure 6**).

7) The Indication class represents an advice of formulation in treatment of health problem and, regimen of the formula. Regimen class contains information of administration time and frequency of using the formulation.

8) The Adverse reaction class represents the adverse reactions related to herbs or formulations. The adverse reaction includes the adverse reaction severity which can be classified into three sub-classes-mild, moderate and severe adverse reactions.

9) The Finished Product Form class represents the forms of herbal product use in Thai herbal medicine classified according to the physical form of products**.**

10) The Clinical Warning class represents warning information of herbs or formulations in terms of contraindication, precaution and other special conditions of user. The Special Condition class has been defined under heading include pregnancy stage, breastfeeding period, age and medicine which contraindicate with herbs or formulations.

The relationships between these classes were defined by object properties. In THMO, important object properties are described as shown in **Table 3**.

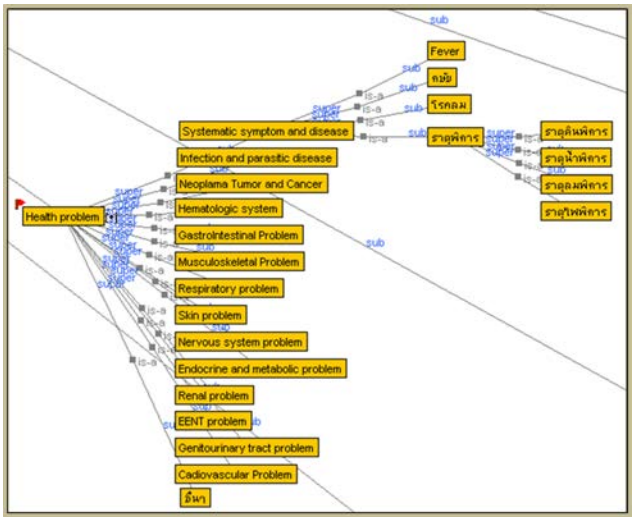

Figure 6 The Health problem hierarchy

Table 3 The important object properties in THMO

Object properties	Description
hasPlant	Provides any of plant information which include plant botanical name, taste of plant and part of plant use as herb material
hasTasteEffect	Relate Taste with the Effect of Taste to Tri-That which can be describe in two type-aggravation and depletion
hasIndication	Relate the Formulation with the indication of the plant or formulation
hasAdverseReaction	Relate the Formulation with the Adverse reaction of formulation
hasDosageForm	Relate the Formulation with the Dosage of the formulation of Thai tradition medicine
hasClinicalWarning	Relate the Formulation with the clinical warning of plant or the Formulation
UseMethod	Relate the Dosage form with the Use direction of the formulation
hasFormulationPreparation	Relate the Use direction with the Formulation preparation of herbal medicine
hasPlant	Provides any of plant information which include plant botanical name, taste of plant and part of plant use as herb material
hasTasteEffect	Relate Taste with the Effect of Taste to Tri-That which can be describe in two type-aggravation and depletion

Evaluation

The evaluation of THMO was conducted after the ontology schema had been finished. This step aims test the validity of classes, subclasses, vocabularies and relationships identification. Experts are two professional groups-ontology engineering experts and traditional doctors. To be qualified as experts, each was require having at least 3 years work experiences in his/her respective expertise and be still practicing in the field.

In all, eight experts-two in ontology development and six in traditional doctor- agreed to evaluate THMO. The evaluation criteria consist of 4 categories: appropriateness of classes; subclasses; properties identification; and, correctness and reusability of the ontology. Descriptive data analysis was applied to the experts' evaluation score on the ontology. Overall opinions of the experts in both groups are strongly agreed with THMO (85.89 % score). Comparing across 4 categories, the most strongly agreed category is correctness and reusability of the ontology, 90.00 % ($\bar{X} = 9.00,\ SD = 0.00$) and 91.67 % ($\bar{X} = 9.17,\ SD = 0.98$) in the group of ontology experts and TTM experts respectively. The opinion in other categories are strongly agreed with the THMO in both group (more than 80 %) in terms of scope, classes, sub-classes and properties identification as shown in **Table 4** and **Figure 7**. Based on the result, THMO is generally acceptable and valid in term of ontology development for Thai traditional knowledge base construction.

Application

To demonstrate the application of THMO, we developed a sematic search system for querying of Thai herbal medicine information as shown in Fig 8. For example, querying for 'the herb to treat musculoskeletal problem which can be prepared by fermentation and use safely during pregnancy'. This is a sample of complex query that can be answered by the system based on concept-based search. Through the semantic search system, the answer can be retrieved from the knowledge base accordingly. By permitting users to perform concept-based searching, it facilitates users in filtering out the non-relevant information typically included in keyword-based searching. For example, when the user uses the term 'musculoskeletal problem' as a query term, it may include list of herbs that contains the term in its description including indication and adverse reaction. By using concept-based search, user can express the information need as "has_indication: musculoskeletal problem", which will filter out the herbs having adverse reaction of musculoskeletal problem. In the example query, users can use the concepts of 'health problem' combined with 'use method' and 'clinical warning' concepts. The result from the system provides a list of related herbs or formulations to treat musculoskeletal problem with can be used by fermentation method only whether it is fermented by alcohol, sugar, salt, etc. In this case, we also filter the herbs or formulations which are not safe for pregnancy

Table 4 Evaluation result from experts

Evaluation items	Ontology experts		Traditional Doctors	
	$\bar{X}$	SD	$\bar{X}$	SD
Proper in Scope identification	22	2.83	20.83	1.33
Proper in Classes identification	15.5	2.12	17.17	1.47
Proper in Properties identification	13	1.41	13.17	1.47
Correctness and Reusability	9	0	9.17	0.98

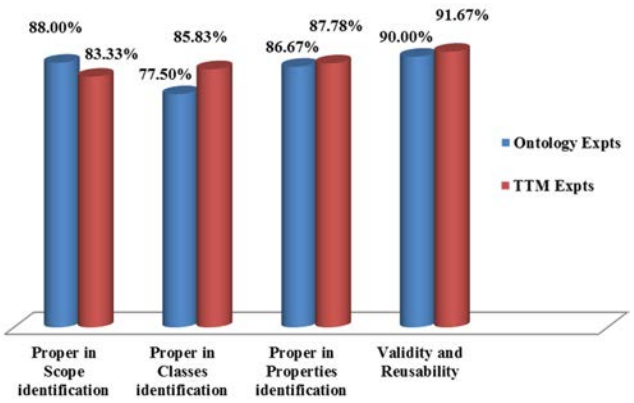

Figure 7 Overall of experts agreement in THMO

women. Thus, the herb or formulation prepared by fermentation with alcohol will not be included in the list of answers.

The application demonstrates that THMO has been developed consistent with the practice and theory of Thai traditional medicine and is useful in providing clinical information of Thai traditional medicine. Thus, healthcare professionals from practicing either traditional medicine or conventional medicine can benefit from adopting and reusing this ontology. It provided functions of concept-based search system which improve efficiency of the information query by excluding non-relevant information items during query answering process.

Conclusion

We have developed a Thai Herbal Medicine Ontology to conceptualize the formal domain knowledge in herb and supported the search for herb in treatment of illnesses. This study described ontology design process for the Thai herb medicine domain. The Thai Herbal Medicine Ontology (THMO) was developed based on the practices and theories of Thai traditional medicine as well as the local communities. It intended to be a reference model of Thai traditional medicine and their implications in clinical level. In addition, it can assist the work of healthcare professional in terms of information finding by means of a concept-based search system.

Although, the THMO has validity in terms of classes, subclasses and relation identification from experts' opinion, but the terminologies of THMO are not standard terms. They need more clarification and standardization in the future. In addition, Thai traditional knowledge was written in Thai language. In the concept extraction process, the translation of concept names from Thai into English cannot refer to the exact meaning of the concept. For example, the sensational properties of herbs which have been classified as hot, cold and su-khum. In Thai traditional medicine used the term called 'Ros or รส' in Thai which can be translated into 'taste' in English. In fact, they are not the taste. They are perceived as property of herbs. Direct translation cannot be used in this case, more precise term for taste should be concern for improvement of the ontology. In addition, this study focus mainly on the ontology development, the performance of the semantic search system for querying of Thai herbal medicine has not been conducted.

The future work of THMO should concern with the terminology standardization of THMO. A semantic search system for querying of Thai herbal medicine should be evaluated in term of informational retrieval model such as precision, recall and/or F-measure. The extension of ontology in its depths and breathe, and to refine the ontology with more domain experts in herbal medicine should perform. This could lead to extending the scope of the ontology that can be used in various information systems including herbal medicine literature search system, herbal medicine recommendation system or decision support system applications**.**

Acknowledgement

The tool of ontology development and semantic search system are supported by Language and Semantic Technology (LST) Laboratory, National Electronics and Computer Technology Center (NECTEC), Thailand. The authors wish to thank the LST Laboratory researchers for advising on ontology development and providing valuable tools and information.

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