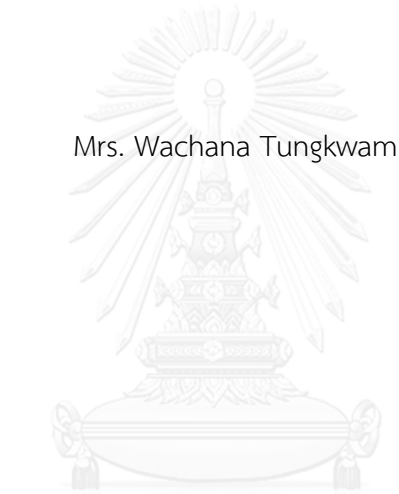
DEVELOPMENT OF THAI HERBAL MEDICINE ONTOLOGY OF THAI TRADITIONAL MEDICINE INFORMATION SERVICE OF CHAO PHYA ABHAIBHUBEJHR HOSPITAL

Mrs. Wachana Tungkwampian



A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Social and Administrative Pharmacy
Department of Social and Administrative Pharmacy
Faculty of Pharmaceutical Sciences
Chulalongkorn University
Academic Year 2014

การพัฒนาออนโทโลยีสมุนไพรไทยของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทย ของโรงพยาบาลเจ้าพระยาอภัยภูเบศร

นางวัจนา ตั้งความเพียร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาเภสัชศาสตร์สังคมและบริหาร ภาควิชาเภสัชศาสตร์สังคมและบริหาร
คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2557

หัวข้อวิทยานิพนธ์	การพัฒนาออนโทโลยีสมุนไพรไทยของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร
โดย	
สาขาวิชา	เภสัชศาสตร์สังคมและบริหาร
อาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก	ผู้ช่วยศาสตราจารย์ เภสัชกร ดร.อนุชัย ธีระเรืองไชยศรี
อาจารย์ที่ปรึกษาวิทยานิพนธ์ร่วม	ดร.มารุต บูรณรัช

คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย อนุมัติให้นับวิทยานิพนธ์ฉบับนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญามหาบัณฑิต

.....คณบดีคณะเภสัชศาสตร์

(ผู้ช่วยศาสตราจารย์ เภสัชกรหญิง ดร.รุ่งเพ็ชร สกุลบำรุงศิลป์)

คณะกรรมการสอบวิทยานิพนธ์

.....ประธานกรรมการ

(รองศาสตราจารย์ เภสัชกร ดร.สถิตพงศ์ ธนวิริยะกุล)

.....อาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก

(ผู้ช่วยศาสตราจารย์ เภสัชกร ดร.อนุชัย ธีระเรืองไชยศรี)

.....อาจารย์ที่ปรึกษาวิทยานิพนธ์ร่วม

(ดร.มารุต บูรณรัช)

.....กรรมการ

(อาจารย์ เภสัชกรหญิง ดร.สุนทรี วัชรดำรงกุล)

.....กรรมการภายนอกมหาวิทยาลัย

(เภสัชกรหญิง ดร.สุภาภรณ์ ปิติพร)

วัจนา ตั้งความเพียร : การพัฒนาออนโทโลยีสมุนไพรไทยของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร (DEVELOPMENT OF THAI HERBAL MEDICINE ONTOLOGY OF THAI TRADITIONAL MEDICINE INFORMATION SERVICE OF CHAO PHYA ABHAIBHUBEJHR HOSPITAL) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ภก. ดร.อนุชัย ธีระเรืองไชยศรี, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร.มารุต บูรณรัช, 90 หน้า.

วิทยานิพนธ์ฉบับนี้ มีวัตถุประสงค์เพื่อออกแบบพัฒนาฐานความรู้ออนโทโลยีสมุนไพรไทย และทดสอบการประยุกต์ใช้ออนโทโลยีในรูปแบบเครื่องมือค้นหาข้อมูลพืชสมุนไพรของศูนย์สารสนเทศด้านการแพทย์แผนไทย ของโรงพยาบาลเจ้าพระยาอภัยภูเบศร โดยได้ศึกษาค้นคว้าข้อมูลขององค์ความรู้สมุนไพรไทยและเภสัชกรรมไทย การสนทนากลุ่มเพื่อรวบรวมข้อมูล นำมาออกแบบออนโทโลยีสมุนไพรไทยเพื่อเป็นฐานความรู้สมุนไพร ที่ประกอบด้วยแนวคิด (concepts) และความสัมพันธ์ระหว่างแนวคิด โดยมีแนวคิดสำคัญที่เกี่ยวข้อง ได้แก่ สมุนไพร (Herb Material), สูตรตำรับ (Formulation), รูปแบบผลิตภัณฑ์สำเร็จรูป (Finished Product Form), คำเตือน (Clinical Warning), รสยา(Taste), ตรีธาตุ (Tri-That), ปัญหาสุขภาพ (Health Problem) และ วิธีการใช้ยา (Use Method) ออนโทโลยีสมุนไพรไทยที่พัฒนาขึ้นได้รับการประเมินโดยผู้เชี่ยวชาญ ได้แก่ ผู้เชี่ยวชาญด้านการพัฒนาออนโทโลยีและผู้เชี่ยวชาญด้านการแพทย์แผนไทย เพื่อประเมินความถูกต้องของการกำหนดแนวคิด การสร้างความสัมพันธ์ และการประยุกต์ใช้ซ้ำ ผลการประเมินพบว่าผู้เชี่ยวชาญทั้งสองสาขาเห็นด้วยกับโครงสร้างและองค์ประกอบของออนโทโลยีในด้านความถูกต้องเหมาะสม และเห็นด้วยมากที่สุดในด้านการพัฒนาต่อยอดและการนำไปใช้ซ้ำกับฐานความรู้อื่นในอนาคต และเพื่อให้ออนโทโลยีที่พัฒนาขึ้นสามารถนำไปใช้ได้จริง ออนโทโลยีจึงถูกถ่ายทอดในรูปแบบระบบค้นหาข้อมูล (semantic search system) เพื่อเป็นส่วนที่ผู้ใช้งานสามารถใช้สืบค้นหาข้อมูลสมุนไพรที่ต้องการได้ และพบว่าการสืบค้นในรูปแบบ concept-based นี้สนับสนุนให้การค้นหามีประสิทธิภาพดีและมีความถูกต้องแม่นยำมากยิ่งขึ้น

ภาควิชา	เภสัชศาสตร์สังคมและบริหาร	ลายมือชื่อนิสิต .....
สาขาวิชา	เภสัชศาสตร์สังคมและบริหาร	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....
ปีการศึกษา	2557	ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5476352233 : MAJOR SOCIAL AND ADMINISTRATIVE PHARMACY
KEYWORDS: HERBAL MEDICINE, ONTOLOGY DEVELOPMENT, SEMANTIC SEARCH

WACHANA TUNGKWAMPIAN: DEVELOPMENT OF THAI HERBAL MEDICINE ONTOLOGY OF THAI TRADITIONAL MEDICINE INFORMATION SERVICE OF CHAO PHYA ABHAIBHUBEJHR HOSPITAL. ADVISOR: ASST. PROF. ANUCHAI THEERAROUNGCHAISRI, Ph.D., CO-ADVISOR: MARUT BURANARACH, Ph.D., 90 pp.

This study propose a method for developing a knowledge base of Thai herbal medicine by using ontology techniques and developing its application as a semantic search system. This expected to support the information search of Thai Traditional Medicine Information Service (TTM-IS) of Chao Phya Abhaibhubejhr Hospital. This study used multi-research methodology include 1) Thai herbal medicine knowledge extraction by adopting method triangulation 2) ontology development technique to create concepts and relationships among the concepts in domain knowledge and 3) ontology evaluation for validation and conformability of Thai herbal medicine ontology (THMO) by experts using a questionnaire and a focus group discussion. 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 agreed with THMO regarding concept identification, relationship identification, correctness and reusability. The application of ontology as prototype of sematic search system was found to be useful in facilitating users query process in finding corrects information on Thai herbal medicine.

Department:	Social and Administrative Pharmacy	Student's Signature .....
		Advisor's Signature .....
Field of Study:	Social and Administrative Pharmacy	Co-Advisor's Signature .....
Academic Year:	2014	

กิตติกรรมประกาศ

I am using this opportunity to express my sincere thankful to every who supported me throughout the course of my study. It will not be possible without the support of all staffs and colleagues for assistant and supportive. I am thankful for their time and opportunities to let me complete this study.

I would like to express gratitude to my advisor, Dr. Anuchai Theerarungchaisri, for his advice, coaching and support in completion of my thesis.

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. I would like to express my sincere thankful to Dr. Marut Buranarach for advising on ontology development and providing valuable information and tools from LST. I am thankful Mr.Taneth Ruangrajitpakorn for kindly suggestion on ontology development.

In addition, I would like to thank Mr.Disathat Rojanarak for advice and suggestion on my thesis writing.

Finally, I would like to thank my family and friends for encouraging me to perform the best of my abilities.

สารบัญ

หน้า

หน้า

List of Tables

List of Figures

Chapter I

INTRODUCTION

Brief Background

Traditional medicine, including herbal medicine, has been, and continues to be, used in virtually every country. The global market for traditional medicine was estimated at US$ 83 million annually in 2008, with a rate of increase that has been exponential (Zhang & Robinson, 2011). The “back-to-nature” and “health conscious” global trends have partly contributed to the welcoming and acceptance of herbal medicine and dietary supplements as a means of health care and health promotion (Chokevivat, Chutaputti, & Khumtrakul, 2005). Consumers’ percept herbal medicine as less toxic than chemicals or allopathic medicines.

In 1978, the World Health Organization (WHO) has issued the Alma-Ata Declaration on primary health care urging member states to use indigenous medicine as well as herbal medicine. In 2002, WHO launched the traditional medicine strategy. The main objectives of the WHO Traditional medicine activities are (WHO, 2002):

- To facilitate integration of traditional medicine into the national health care system by assisting Member States to develop their own national policies on traditional medicine.

- To promote the proper use of traditional medicine by developing and providing international standards, technical guidelines and methodologies.

- To act as a clearing-house to facilitate information exchange in the field of traditional medicine.

The WHO strategy is to facilitate the integration of traditional medicine into nation health systems and promote the collection and use for better evidence on quality, safety and efficacy. This is a starting point for the world to look back on wisdom or traditional knowledge.

In Thailand, Thai herbal medicine is well recognized. One reason is because modern medicine has not been the answer for the good health of Thai people since a large amount of the country's healthcare budget is spent on high technology medical equipment and pharmaceutical products to treat major health problems, i.e. diabetes, hypertension, cardiovascular diseases and various types of cancer. In order for Thailand to become more cost-effective and self-reliant, the Thai government has looked back at the country's heritage in healthcare, and acknowledged the role of Thai traditional and herbal medicine. This can play an important role in the treatment of common diseases, disease prevention and health promotion. The policy support for Thai Traditional and herbal medicine began during the 4th National Economic and Social Development Plan (1977-1981), at which time 57 medicinal plants were selected and recommended for the treatment and relief of 19 groups of common diseases. During the 7th-9th National Economic and Social Development Plan (1992-2006), Thai traditional and herbal medicine knowledge was developed through research and the improvements were made on the standard for successful integration into the health service system and for health promotion through self-care. The 10th National Economic and Social Development Plan focused on research

and development for improving the quality of life and creating economic value, managing intellectual property rights derived from research and development, and developing personnel so that they would be capable of integrating Thai traditional medicine into the modern medical system. Moreover, the National List of Essential Medicines (NELM), first complied in 1999, broaden the list of drugs derived from herbs to support Thai traditional medicine use and acceptance among the Thai population. The latest version of NLEM, 2011, contains 71 herbal medicinal products. The prior version produced in 2006, contained only 19 herbal medicinal products. Another support from the government sector was the Ministry of Public Health (MOPH) policy for easily access to herbal medicines. This was accomplished by revising the criteria and broadening the groups of medicines and symptoms so that more traditional household drugs could be registered and sold in all pharmacies (Chokevivat, Wibulpolprasert, & Petrakard, 2012).

As a result of government support, the demand for Thai traditional and herbal medicine is increased. That emerging popularity of Thai herbal medicines caused an increasing in the number of herbal product manufacturers and herbal products launched into markets. This can be observed in the growth of manufacturing programs such as the one at Abhaibhubejhr, which experienced annual growth rates rising in each successive year from 2002 to 2012. Their number of products manufactured rose from 66 items in 2001 to 110 items in 2012 and sale increased from 16 million baht to 230 million baht in the same period.

Rational and Statement of the Problem

Finding reliable information on herbal use by the general public is difficult because of lack of trustable sources of information, on Internet may exist in large volumes, but it is very difficult to search for specific information, and often search results must be interpreted by specialists or experts, the number of which is limited.

Chao Phya Abhibhubejhr Hospital (CAH) recognized this problem. In 2006, CAH established Thai Traditional Medicine Information Service (TTM-IS) under the responsibility of the Drug Information Service (DIS) of the Pharmacy Department. The objective of this unit is a protect consumers by providing appropriate information on herbal and their use for health care professionals in the hospital and consumers. A consultation unit in traditional and herbal medicine provides Thai herbal medicine experts consultations and provides useful herbal medicine information for users. Approximately 30 questions are received by the unit each day. The most frequently asked questions include, “What are the indications of certain herbs?”, “Is it safe to consume certain herbs?” and “What herbal remedies are suitable for my health condition?”.

In the process of answer finding, staffs use a keyword-based search technique from general search engine such as Google, Yahoo or Pharmacy department electronic files. Documents or information retrieved only if they contain keywords specified by the staff. Name of herbs, diseases or symptoms can be called in different name depend on the region. The result of keyword search in general search engine may not cover other related keywords or synonyms because of multiple

synonyms. For example, searching for the indication “Yor (ยอ)” by using it as a keyword. In general, “Yor” is the most common name and widely used in many regions. But, in some region it can be called in other name such as Indian mulberry, *Molindacitrifolia*or Mak-ta-suea (หมากตาเสือ). General search may find only Indian mulberry and *Morindacitrifolia.* Mak-ta-suea is not a common name and only some region use this term to call “Yor”. The search result of using Mak-ta-suea as a search keyword may not retrieve because it is an uncommon term and the relationship between Yor and Mak-ta-suea has not been defined in the search engine. With ontology employed search system, relations of name, synonym and other related information will be defined in the process of ontology development. Hence, a search result will display all related information of a certain keyword. In this case, using either Yor or Mak-ta-suea as a keyword search, the result will be retrieved. Other medicinal plants which have indication related to “Yor” will be finding. This means ontology help increasing performance of search system in finding correct and precision result. Other problem of finding answers is sources of information which experts use is still largely text based, not well organize and difficult and time consuming to search for certain answer. Information comes from various sources, has different formats, is scattered, and is not well organized. Most such information is kept in text document form. Using this knowledge, and eventually reusing it, is not convenient.

Nowadays ontology is now pervasive in biomedicine, it serve the standardized terminology, to enable access to domain knowledge (Hoehndorf, Dumontier, & Gkoutos, 2012), to manage various sources of information (Siricharoen, 2009). Ontology provides an understanding of the structure of information or knowledge by

defining related terms and concepts in herbal medicine and their relationships.

In biomedicine, there is varieties ontologies i.e. medical ontology or disease-based ontology. In the future, interoperability between ontologies, including herbal medicine ontology, will help to enhance searching performance to cover most related information. Ontology allows common knowledge sharing and the reuse of knowledge .

In this study, ontology is used to define all related tems, concepts, classes, sub-classes and properties of Thai herbal medicine knowledge. Hence, the relations of each concept will be defined to create an ontology map. The result from the first stage is ontology map of Thai herbal medicine terms, concepts, classes, sub-classes and properties. The second stage is creating the Thai herbal medicine database system and integrate ontology map to the search system of the database. The result from this stage is Thai herbal medicine database that integrate Thai herbal ontology in the search system.

The output of the study is expected to support an information searching process of the TTM-IS, consume less time and produce more relevant and precise information. Ontology will act as facilitator for the database in searching for require information.

Purpose of the Study

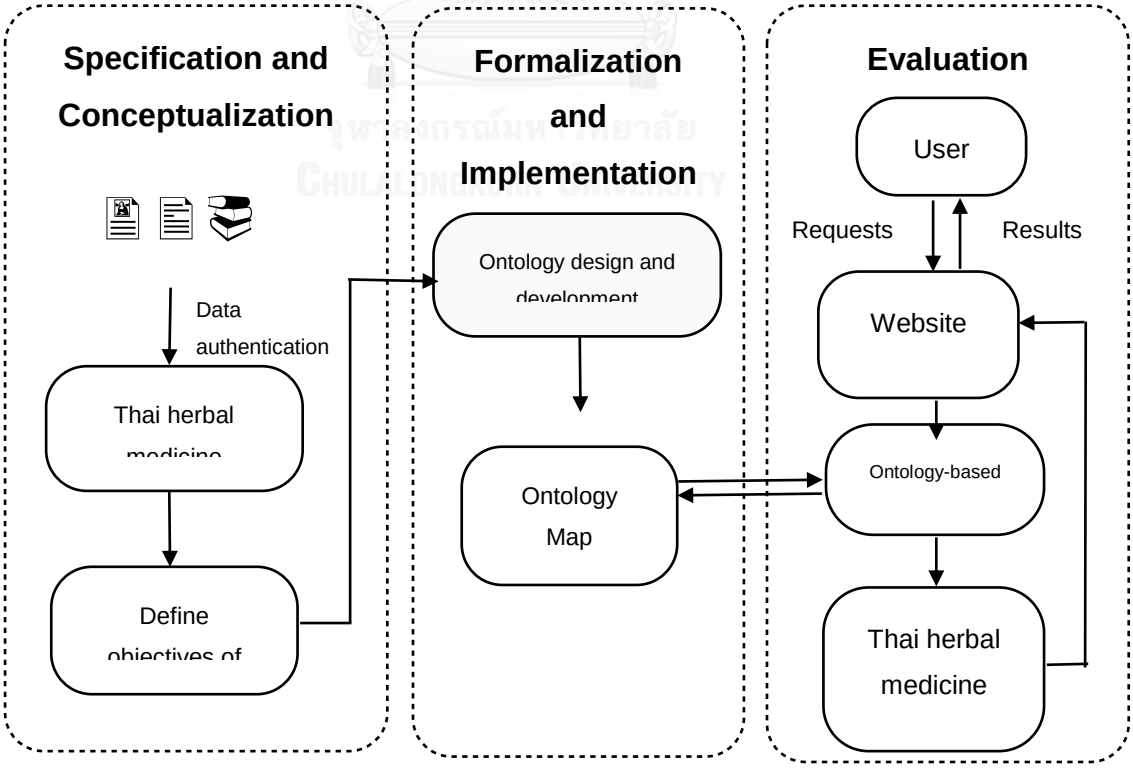
To develop an ontology of Thai herbal medicine knowledge of Thai Traditional Medicine Information Service (TTM-IS) of Chao PhyaAbhaibhubejhr Hospital (CAH)

Research Questions

1. What are the topics commonly used for searching herbal medicine knowledge of Thai Traditional Medicine Information Service (TTM-IS) of Chao Phya Abhaibhubejhr Hospital (CAH)?

2. What is the ontology of the Thai herbal medicine?

Conceptual framework



Operational Definitions

- **Thai Herbal Medicine**-herbs or medicinal materials are used for the treatment diseases or symptoms in Thai Traditional Medicine
- **Ontology**-a description of the concepts and relationships among them that can exist for an agent or a community of agents in a specific knowledge domain
- **Thai herbal medicine terminology**-a study to define and represents term used in Thai Herbal Medicine
- **Semantic search system**-the prototype system for searching and displaying the result

Scope of the Study

1. Scope of domain knowledge in herbal medicine selected from Chao Phya Abhaibhubejhr Hospital Drug List (Herbal medicine list) which five main health problems which can be treated with herbal medicine These are:

- Gastro-intestinal problem
- Musculoskeletal problem
- Respiratory tract problem
- Diabetes
- Fever

2. Scope of data collection

2.1. Herbs or medicinal plants

2.2. Scientific name

2.3. Synonym

2.4. Local name

2.5. Family

2.6. Properties of herbs

2.7. Pharmacological effect/ ethnopharmacological property

2.8. Taste (3 major taste- รสประธาน)

2.9. Safety and adverse reaction

2.10. Reference

2.11. Herbes application

- Formulas/recipes
- Indication
- Preparation
- Dosage form

- Dose
- Precaution and contraindication

2.12. Symptoms

- Symptoms name
- Symptoms description

Expected Benefits

1. Thai herbal medicine terminology that were used in Traditional Medicine Information Service (TTM-IS) of Chao PhyaAbhaibhubejhr Hospital (CAH) be defined and organized
2. Ontology map of Thai herbal medicine in Traditional Medicine Information Service (TTM-IS) of Chao PhyaAbhaibhubejhr Hospital (CAH) will be used as one set of ontology to mapping with other ontology and enhance the ontology of herbal medicine knowledge domain and other related knowledge domain

Chapter II

LITERATURE REVIEW

This study is mainly focused on using ontology to organize and develop Thai herbal medicine knowledge terminology. Ontology method helps to define the terms, concepts and hierarchical relationships among them. Ontology and it application are described below.

1. Definitions of ontology
2. General ontology development processes
3. An ontology-based health information system design
4. Ontology evaluation approaches
5. Ontology development tool
6. Review of related literatures
7. Database perspective and roles of domain ontologies in database design
8. Semantic search system and evaluation

1. Definitions of ontology

Ontology is the concept which is separately identified by domain users, and used in a self-contained way to communicate information . It is a knowledge model that represents a set of concepts within a domain and the relationships among these concepts (Riano, Real, Lopez-Vallerdu, Campana, & Recline, 2012). Ontology help to define a common vocabulary set for researchers who need to share information in a particular domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them (Vadivu & Hopper, 2012). Ontology is recognized as an important tool for coping with very great compound and/or multiple sources of information and concepts . In other words, ontology refers to the formalization of the knowledge in a domain. It is an extremely important tool for the organization and contextualization of knowledge, particularly in well-bound contexts such as scientific research, or within individual organizations (Brewster & O'Hara, 2007). It also provides understanding of the structure of information, and, interoperability between different applications or database systems. In some cases, ontology is used to refer simply to controlled terminologies (A. C. Yu, 2006).

In general, ontologies can be used for various purposes according to (Noy & McGuinness, 2001):

1) To share common understanding of the structure of information among people or software agents. This is one of the most common goals in developing ontologies

2) To enable the reuse of domain knowledge

3) To make explicit domain assumptions

4) To make domain knowledge from the operational knowledge

5) To analyze domain knowledge

6) To do ontology-based search system

According to (A. C. Yu, 2006) biomedical ontology is useful for:

Terminology management

Because of the complexity of medical or biological information, it is difficult to manage a healthcare information system for effective communication among healthcare professionals. It requires deep analysis and formal representation of the meaning of terms. Adoption of the ontology approach helps to facilitate this task and assures that information will be in a form which is usable by computers.

Integration, interoperability and sharing

In biomedicine, these are important for purposes of the facilitation continuity of healthcare; in biological research, it facilitates the sharing of experimental data among researchers.

Knowledge reuse and decision support

Ontology is an application independent, which helps to create knowledge bases and can be reused in new systems without additional system development

Basic building components of ontology include: concepts or classes, properties of each concept describing various features and attributes of concepts. Details of all these ontology components are presented as below.

- *Concepts/classes* can refer to what is generally in reality or what we are interested in
- *Properties* are details to describe each concept
- *Relationships* explain how two terms or more are related. If the relation describes a relationship among two terms, it is called a slot. If the relationship describes more than two, it is called function.
- *Axioms* are logical statements that assumed to be true without proof
- *Instances* represent specific entities from the domain knowledge base

Example of ontology component in Fig. 1

- Concept is Car, Price and Brand
- Properties of Price is a number represent price of cars and Brand is a name of car's brand

- Relationship of Car to Price and Brand are hasPrice and hasBrand respectively

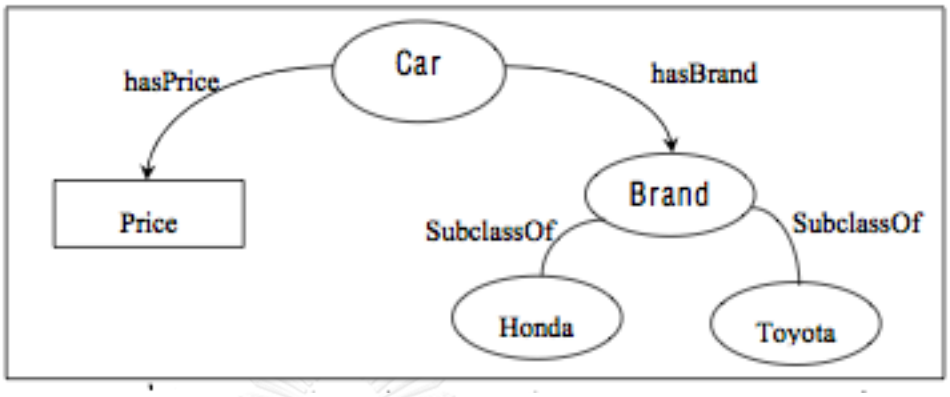


Figure 1Example of ontology components (Exerpted from Prakittikornchai, 2007)

2. Ontology development processes

There are various methodologies for developing an ontology. The most common methodology is described in defining classes/concepts in ontology, arranging the class/concepts in taxonomic hierarchy, defining slots an describing allowed values for these slots and filling in the value for slots of instances. Details are presented as below:

2.1 Determine the domain and scope of the ontology

Ontology developments start by determining scope by answering several basic questions:

- What is the domain that the ontology covers?

- For what purpose are we going to use the ontology?

- For what type of questions should the information in the ontology provide answers?

- Who will use and maintain the ontology?

All these questions will help to limit the scope of the model ontology and answers can be changed during the development process.

2.2 Consider reusing existing ontologies

This is a step designed to explore and check whether someone has done the same kind of domain knowledge. This might be necessary for the system to interact with other applications that have already been committed to particular ontologies or controlled vocabularies. Ontology is in electronic form and can be import easily into the system users need.

2.3 Enumerate important terms in the ontology

This step list related terms which will be used in the ontology, what are the properties of all terms are or what terms need to be explained to users. These depend on the scope to the ontology. Comprehensive list of terms is very important in order to represent all domain knowledge and their relations.

2.4 Define the concepts and the concepts hierarchy

This is the step in which to define terms, concepts, properties, axioms and instances. There are several possible approaches.

A top-down development process starts with the definition of the most general concepts in the domain and subsequent specialization of the concepts.

A bottom-up development process starts with the definition of the most specific classes, the leaves of the hierarchy, with subsequent grouping of these classes into more general concepts

A combination development process is a combination of the top-down and bottom-up approaches. It starts with defining more salient concepts first and then generalizes and specializes them appropriately.

2.5 Define the properties of concepts

To provide more information explaining each concept, the defining properties of concepts is necessary. In step 2.3, the concepts have been chosen. This step is the step to determine what is the properties of each concept are.

3. An ontology-base health information system design

Another ontology development process, *A Four Stage Approach for Ontology-based Health Information System Design* (Kuziemsky & Lau, 2010) describes and illustrates methodological stages to capture user knowledge in a biomedicine area. This methodology will be applied in this study because the methodology is more

specifically suited to the ontology development for Thai herbal medicine which is concluded as one of the biomedicine area. Indeed, the method support ontology based Health Information System (HIS) development which can be conform with the ontology-based search engine in this study. The four stages as shown in Fig.2

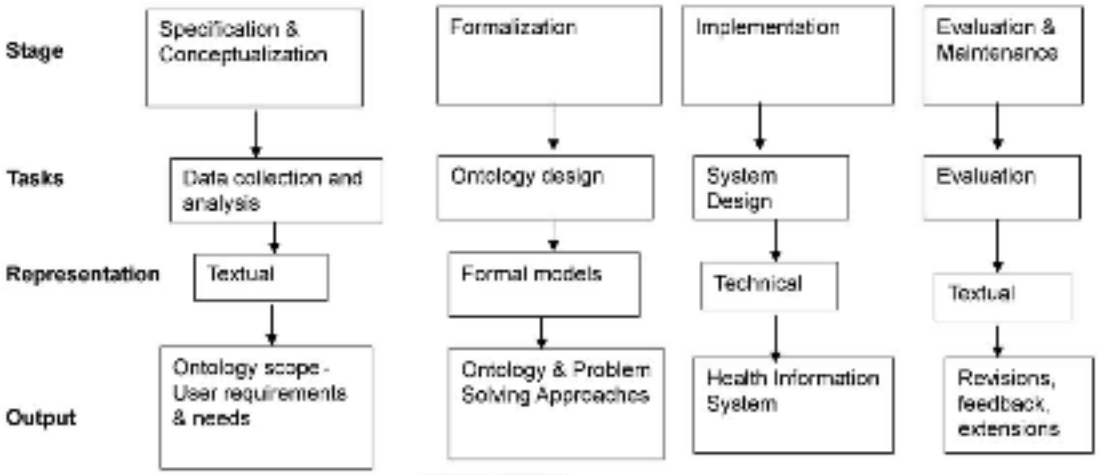


Figure 2 Four stage approach for ontology base HIS design

Stage 1-specification and conceptualization

Specification identifies the purpose and scope of ontology while conceptualization provides the concepts, vocabulary and relationships for ontology design. There are two tasks at this stage: Data collection and data analysis

Data collection

The specific data sources used for a project will vary according to the study context. To identify ontology scope and purpose there are three goals the data sources need to accomplish.

- To be able to validate concepts and processes

- To incorporate conceptual models and other relevant research literature as a meal of liking research and practice

- The use of historical data such as retrospective patient cases, to understand current data collection practices and how that data formalized into information and knowledge to be returned to end users.

speaks of a method called Participatory Design (PD). PD helps to design a product and ensures the usability and utility of the product by engaging end users in the design process. It is the way to acquire understanding and to make sense of the traditional, tacit and often visible ways people perform their everyday activities. In the HIS, it was used to involve users in information system design: interface, data entry and retrieval tools. The main strength of PD is that it provides a means of user engagement to obtain a rich perspective on clinical practice. It enables an accurate domain knowledge representation in ontology development.

Data analysis

In the literature, it used Grounded theory (GT) methodology for data analysis development. The coding cycle contains three coding: open, axial and selective coding.

- Open coding involves the initial examination, comparison, conceptualization and categorization of data to establish concepts and categories

- Axial coding refines the concepts and categories and establishes connections between them

- Selective coding establishes the core categories and links the different concepts and categories to it

The strength of GT is to code data into concepts and categories to develop a theoretical based understanding about the data.

Hybrid grounded theory-participatory design method (Figure 3) was conceived to obtain the data and code it for ontology.

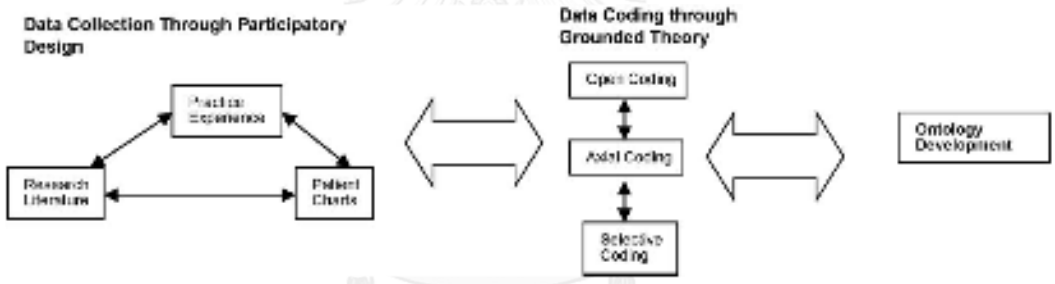


Figure 3 Participatory design and ground theory (excerpt from (Kuziemsky & Lau, 2010))

The end product of this stage is textual data that has been coded. The selective codes from GT represent the scope of ontology and become the starting point for the formalization stage.

Stage 2- Formalization

The formalization extends the selective codes by developing hierarchies and relationships such as IS_A and PART_OF relationships for the ontology. The formalized ontological models were developed using the Protégé 2000 ontology

development tool (Musen, 2000) with frames as the representation language.

This stage involves the development of the domain ontology, sub-ontologies and problem-solving approaches. Domain ontology and sub-ontologies represent the structure and relationships of the ontology while problem-solving approaches provide specific solutions to domain problems.

Stage3-Implementation

Implementation of the ontology as a computer-based tool involved conversion of the ontology and problem-solving approaches into a technical architecture. The domain knowledge and sub-ontologies were implemented as Health Information System components i.e. the database schema, decision support or information retrieval tool. Microsoft Access was used to develop prototypes with the Visual Basic to program the added functionality. Tasks in the stage involve converting the domain and sub-ontologies into database tables. The ontology concepts become tables in the database tables. The relationships between the ontology concepts are implemented as relations between the various datable tables. Another task is to develop user views of the computer based tools. This consists of developing the forms, rules, reports and interfaces that enable users to interact with the system. For examples, the database relationships become the basis for access data elements and the problem-solving approaches become rules, queries, screens and the means of navigating through the database content.

An example of the implement stage is shown in figure 4. The current case sub-ontologies were developed (a) from current case of patient pain and converted into tables in the database as seen in (b). The user interface was developed by using

the problem-solving approach, in this case a decision support tool for pain management. It is a computer-based tool that provides data entry and the display of results.

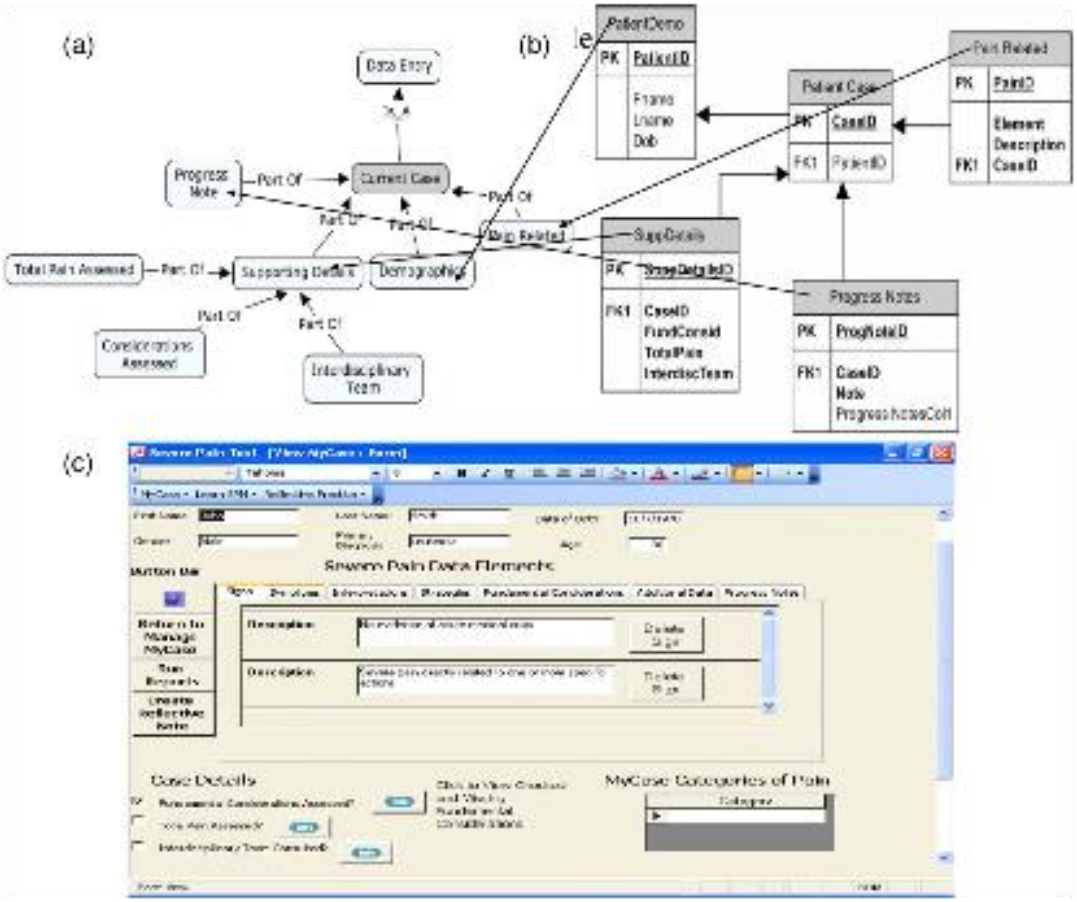


Figure 4 (a) sub-ontologies development, (b) database tables implementing the ontology, user interface from computer-based tool.(excerpt from (Kuziemsky & Lau, 2010))

Stage 4-ontology evaluation

Ontology evaluation can be divided into two methods: technical evaluation and user evaluation.

Technical evaluation

Technical evaluation involves verification and validation of the ontology concepts and vocabulary. This can be performed by using qualitative or quantitative methods or combinations of both. In the literature, the qualitative evaluation method was completed as part of establishing the GT-PD method. When derived ontology concept, GT-PD process allow users to verify ontology concepts.

User evaluation

Usability test was employed. This was not a direct evaluation of the ontology, it more likely to test of the implementation. The implementation testing could be considered as a more relevant evaluation form a HIS perspective. The reasons are clinicians do no concern on correctness or other aspects of ontological quality, but rather they want the tools which can provide value for their care delivery. The usability testing processes evaluate both usefulness and usability of the computer-based tool. The testing use both qualitative and quantitative method.

The usability use five subjects do three cases of patient presenting with severe pain. They were asked to do task and subtasks. After finished their tasks the usability were coded and quantified. The most common issues were system understandability and navigation. Usefulness of the computer-based tool was assessed by asking open-ended question following each of the three testing cases about different features of the computer-based tool. Specific questions were asked about each of the domain ontology concepts to assess the contribution each concept made to the design of the computer-based tool. The interview questions included queries on specific feature (i.e. how helpful was the ability to solve the

problem?), and general questions (i.e. does the computer tool fit with your normal practice work flow?). Quantitative method was used by asking subjects to give a score on how helpful of the tool was.

4. Another Ontology Evaluation Approaches

In (J. Yu, Thom, & Tam, 2009), the study suggested three main approaches to ontology evaluation: gold standard evaluation, criteria-based evaluation and task-based evaluation.

- *Gold standard evaluation*: This approach compares ontology with ontology. It determines the accuracy of discovered relations generated form certain proposed ontology with the existing ontology. It seem not so useful outside the domain of ontology learning because if a known gold standard ontology exists then there is no reason to evaluate other ontologies.

- *Criteria-based evaluation*: This approach is an evaluation base on criteria such as consistency, completeness, conciseness, expandability and sensitivity. This kind of evaluation can be performed only by human. It is difficult to perform automate test. The criteria focus on the characteristics to the ontology in isolation from the application.

- *Task-based evaluation*: This evaluation based on competence of ontology in completing tasks. This can judge whether ontology is suitable for the application or task in a quantitative manner by measuring its performance within the context of the application.

This study will use only technical evaluation to verify and validate ontology by applying criteria-based and task-based evaluation approach. Criteria-based evaluation is a qualitative approach, using experts to evaluate ontology in criteria of correctness, consistency, completeness and conciseness. Task-based evaluation is a quantitative approach to evaluate correctness and coverage of information retrieve from ontology search system.

5. Ontology development tool

5.1 Protégé

For ontology development, there are several tools for constructing the hierarchy of domain knowledge or ontology knowledge base. One of the most popular tools is Protégé (http://protege.stanford.edu/overview/). It was developed by Standford Center for Biomedical Informatics Research, Standford University School of medicine. The functions of the tool allow a rich set of knowledge-modeling structures creation and provide actions to support the creation, visualization, and manipulation of ontologies in various representation formats. This tool supports two main ways of modeling ontologies: the Protégé-Frames and Protégé-OWL.

- The Protégé-Frames editor enables users to build and populate ontologies that are frame-based, in accordance with the Open Knowledge Base Connectivity protocol (OKBC). In this model, an ontology consists of a set of classes organized in a subsumption hierarchy to represent a domain's salient concepts, a set of slots associated to classes to describe their properties and relationships,

and a set of instances of those classes-individual exemplars of the concepts that hold specific values for their properties.

- The Protégé-OWL editor enables users to build ontologies for the Web Ontology Language (OWL). "An OWL ontology may include descriptions of classes, properties and their instances. In ontology, the OWL formal semantics specifies how to derive its logical consequences, i.e. facts not literally present in the ontology, but entailed by the semantics. These entailments may be based on a single document or multiple distributed documents that have been combined using defined OWL mechanisms"

5.2 Hozo

Hozo is an ontology editing tool which has been developed by the Institute of Scientific and Industrial Research (ISRI), Osaka University (Kozaki, Sunagawa, Kitamura, & Mizoguchi, 2007). It was developed based on both of a fundamental consideration of an ontological theory and a methodology of building an ontology. The functions provide users with a graphical interface which and browse and modify an ontology locally. The features of Hozo describe as below:

- Support role of representation of ontology
- Visualization of ontologies

- Distributed development based on management of dependencies between ontologies

Hozo is not support the OWL editor as Protégé, but it allows an exporting of ontology to OWL and RDF language in order to further integration with other applications.

6. Review of Related Literatures

Ontology has become the knowledge representation medium of choice in recent years in a range of computer sciences and biomedicine. Several researches have applied ontology to their work.

6.1 Ontology on herbal or traditional medicine

In traditional medicines, traditional Chinese medicine (TCM) has become the most popular alternative medicines. Ontology has been applied to manage and organize basic terminologies and assertions representative of TCM (Gu, 2010). The study extract terms and concepts of TCM focused on five element theory, TCM disease principle, diagnosis which mainly focused on syndrome, rules of treatment and therapies. The result of the study defined 821 classes or concepts in TCM, 26 properties, 134 axioms and 78 properties of axioms in their ontology.

In India, ontology was designed and developed for mapping of Indian medicinal plants with standardized medical terms (Vadivu & Hopper, 2012). Because of the Information about medicinal plants is scattered in text form and unconstructed, search engines are not efficient and manual processing is required.

Because it was difficult to browse for medicinal uses of herbs, ontology mapping was used to organize and standardize terms and relationships.

In African traditional medicine (ATM), ontology was used to define the taxonomy of selected herbs in ATM and their botanical hierarchy, it also was used in defining relationships among herbs and treatment methods (Oladosu, Align, & Mbarika, 2012). In (Kamsu-Foguem, Diallo, & Forum, 2012), ontology was used as an important tool to extract formal model describing ATM. In this case, ATM ontologies include symptoms, medical sign, disease, activity (treatment or diagnosis) and dosing devices. This aim was to facilitate knowledge sharing and reusing.

In Thai Traditional medicine (TTM), Thai herb ontology prototyping has been develop by defining herb concepts of Thai traditional medicines (Prakittikornchai, 2007) in the form of ontology classes and properties as shown on figure 5. The scope of the study cover 27 sets of Thai herbs derived from the data provided by Royal Thai Government Ministry of Public Health's. The study developed user interface to easily find details about Thai herbs, relations of herbs to Thai Traditional medicine, and symptoms and herbs to treat symptoms. This study defined classes of Thai herb which are Thai Herb, Medicine (household remedies), part of use (part of herb which has medicinal property) and symptoms. In medicine class, it can be divided into 6 subclasses according to therapeutic properties of medicine which are blood, carminative, clod, cough, diarrhea and heart condition. In 2004, Thai medicinal plant ontology was developed to classify and provide standard vocabulary in knowledge area related to medicinal plants. The study developed an ontology-based system for querying multiple medicinal plant data sources. The ontology classes included phytochemistry, plant taxonomy, economic botany and

therapeutic categories of herbs. Another application which used an ontology approach can be seen in (Nantiruj, Maneerat, Varakulsiripunth, Izumi, & Shiratori, 2008), in which an e-health advice system with Thai herbs developed with an ontology. The system provided three functions: the Thai herb search, treatment and advice functions. The first two functions were designed using the database query method while the advice function used ontology to define relationships among classes. The ontology classes in this study included: symptoms, personal information, anamnesis, provinces and Thai herbs. The system recommended appropriate herbs to treat symptoms based on users and inference rules. Another e-health system with Thai herb recommendation outputs used ontology to express domain knowledge of Thai herbs. The ontology classes displayed were person, Thai herbs, taste (of Thai herb), symptom, chronic disease and living places. The system provides recommended Thai herbs based on information received.

All of Thai herbal medicine or Thai traditional medicine literature reviewed was developed by computer science experts/engineers. While, evaluation focused only on technical or function of the ontology-based system. The scopes of the ontology developments, from literatures above are not cover all classes and properties of Thai herbal medicine domain knowledge. Diagnosis, treatment and properties of herb based on Thai Traditional Medicine has not been developed. Although, one study included taste of Thai herb as an ontology class but it was not referred to as a basic properties of herbs or appropriate for herbs for personal symptoms. It was used only for recommending herbs which had taste preferred by users. There has been no study that describes the ontology of basic Thai traditional

medicine knowledge or focuses on extracting Thai traditional medicine terminology. It is for this reason that this study will be conducted.

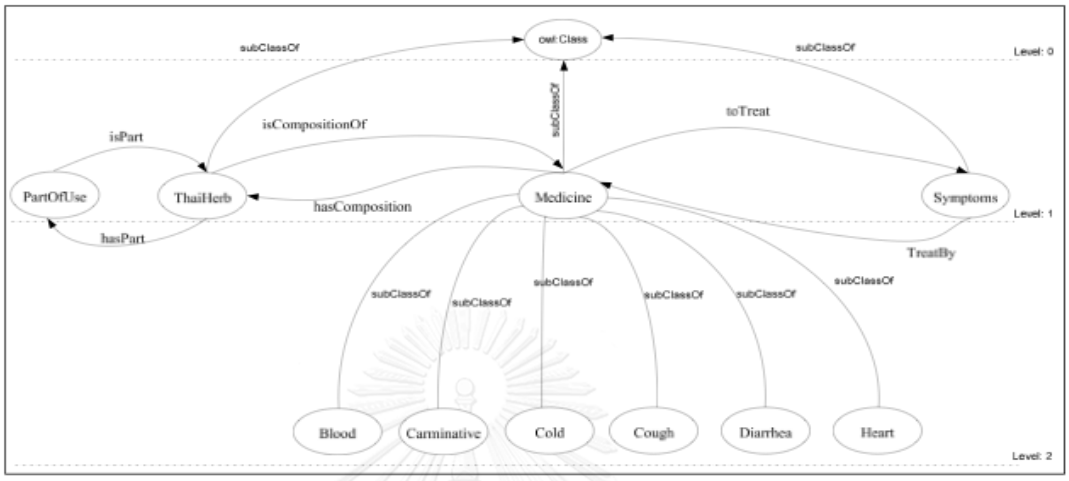


Figure 5 Example of Thai herbal medicine ontology (exempt from (Prakittikornchai, 2007))

6.2 Ontology in search engine development

Ontology can also apply in database and/or search engine development as shown in the following two reviews.

Design and Development of an Ontology Based Personal Web Search Engine (Sakthi Priya, Revathy, Pradeesh, & Rene Robin, 2012)

In this study, an ontology editing tool such as Protégé, an open source ontology editor and knowledge-based framework were used to develop a personal web search engine. This study was used to construct concepts/classes gathered from the World Knowledge Base (WKB) like Wikipedia, WordNet and other sources. Concepts/classes were converted into an ontology database. In this study, MS-Access was use as a database tool, to store all classes and subclasses of ontology.

Search engine was evaluated by using 20 questions to receive feedback in terms of accessibility, navigation, security and efficiency.

Technological Resource Search Engine Based on Ontology (Wang, Mao, Dai, & Sun, 2010)

Traditional search engines based on keyword retrieval are low in precision, because of the lack of user understanding and received huge volume of result which can lead to information confusion. To solve these problems, this study examined the technological resource search engine based on ontology. In the whole system, the core data layer was developed by using ontology techniques to identify concepts, sub-classes, instances and relations. The system established a technological resource indexing according to the ontology base and then establishes technological resource indexing database. The result showed that it helped users to get more precision results and satisfied users better than traditional search engine.

7. Database Perspective and Roles of domain ontologies in database design

7.1 The Database Perspective

Database system concerned with the storage, maintenance and retrieval of the data which is available in the system in explicit form. In database environment, each item or record is separated into several fields which contain the valued for a specific characteristic or attribute identifying the corresponding record which it is linked. The information retrieved will consist of all records or items which are exactly match with the keyword search. In this case, it is difficult to formulate precise to search keyword and the result may include items that may or may not

match the information requests exactly. In ontology employed system, its objective is to achieve better procession and recall in the text retrieval system by query expansion through the use of semantically related-terms (Khan, 2000). Some ontology, it was shown to be potentially relevant to enhanced recall and get more precision result compare to general keyword search.

7.2 Role of Domain Ontologies in Database Design

The database design process generally follows five steps: Planning and analysis, conceptual design, logical design, physical design and implementation. The developer collect information about requirements by review exist information and ended-users interview. Database tends to manage only some for some purpose or part of domain knowledge. In contrast, ontology are intended to give details and explain the world, to capture all domain knowledge and provide understanding of real world because it made of concepts, instances, properties, axioms and relationships. In case of the domain knowledge has various concepts or sources of information. Ontology is advantageous for data modeling and conceptualization according to the four characters of ontology: explicit, formalization, sharing and conceptualization (Wang, 2010). Ontology can be used to help people and machine to communicate concisely by facilitating the information exchange based on semantics rather than just on systax (Calegari & Pasi, 2010).

In searching for interested information and receive more precise result for user, personalized ontology can be applied. Personalized ontology is defined by performing a mapping between the relevant concepts extracted from the visited pages and the concepts of interest extracted from search queries. In

(Calegari & Pasi, 2010), personal ontology is built by considering the relevant concepts extracted from the preferred web page after web search, the user's queries and user's preferred document. Result in extracting useful concepts defined in ontology and used to expand the user's query for better located relevant information, and ontology can be used to re-ranking the results produced by search engine according to the user interests. This methods can be applied to this study in extracting useful concepts from FAQs of TTM-IS which they can refer to ended-user prefer terms. This can improve user's search

8. Semantic search system and evaluation

An evaluation technique of ontology to determine the efficiency of semantic search system can be measured in data retrieving model as precision and coverage. An experimental approach will be apply for this stage by calculation the retrieved objects from the search system result compare to the amount of whole identified objects and relevant objects (in ontology). Correctness and coverage can be conceptualized as below.

Precision refers to the ability of ontology in capturing concepts, classes and relationships correctly according to the frame knowledge. This can be calculated from equation describe below:

$$\text{Precision} = \frac{\text{Number of relevant objects that are retrieved}}{\text{Number of retrieved objects}}$$

Coverage means all relevant concepts; classes and properties in the ontology adequately cover the concepts of the frame of knowledge.

$$\text{Coverage} = \frac{\text{Number of relevant objects that are retrieved}}{\text{Number of relevant objects}}$$

Precision and coverage ratio have range between 0-1. To measure overall precision and coverage of ontology, the frequently asked questions of TTM-IS were used to design the scenario for information retrieving in order to test the efficiency of ontology application.

Table 1 Precesion and coverage score measurement

Scale of measure	Score	Description
precision	1	ontology-based search engine provide correct result according to the reference
	0	ontology-based cannot provide correct result according to the reference
coverage	1	the result cover all relevant objects
	0	the result not cover any relevant objects

Chapter III

METHODOLOGY

The Thai herbal medicine search engine, based on an ontology of Thai herbal medicine and a semantic search system, has been developed to assist information search by the of Thai herbal and Traditional Medicine Information Service (TTM-IS).. This ontology, is designed to be a knowledge information system representing the domain knowledge of Thai herbal medicine and identifying relationships among their terms and concepts.

System Framework

The system framework as shown in Fig. 6 consists of modules of a knowledge base, an ontology, a database and a user interface. Ontology technology was used in creating conceptual knowledge for Thai herbal medicine. The herb database, which was initially created with MS Access, was exported to MySQL database servers. The database data was then integrated into the ontology to create the knowledge base in the RDF (Resource Description Framework) format by using Ontology Application Management (OAM) framework. 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, the user can perform the querying process on top of the provided SPARQL query facility. This chapter focuses on the scope of domain knowledge necessary for answering relevant queries regarding TTM.

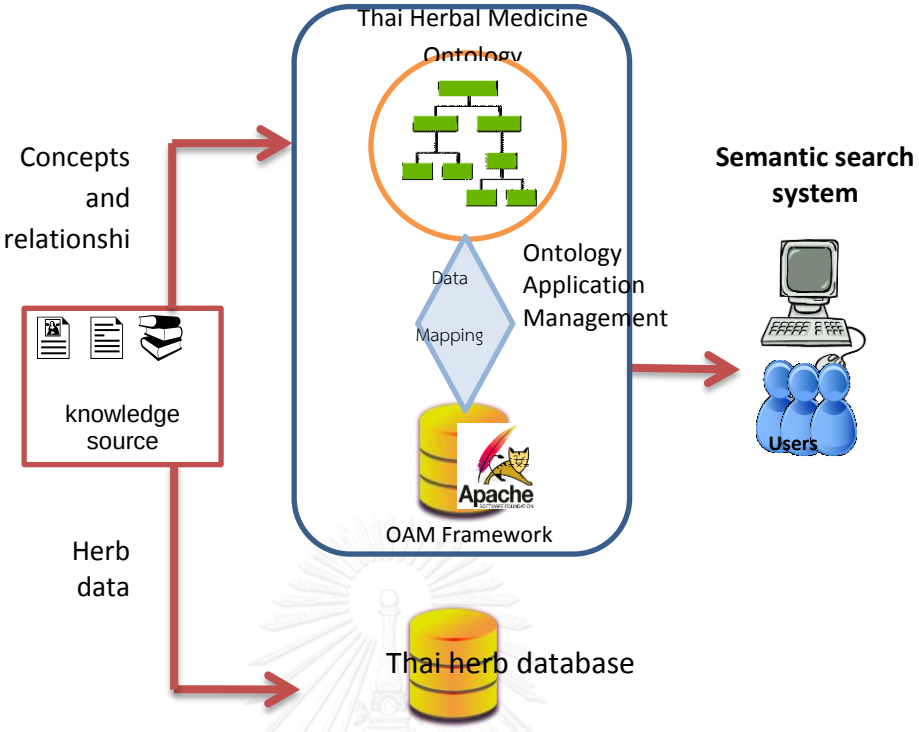


Figure 6 System framework

Materials and Methods

Materials

1) Hozo Ontology Editor, developed by the Institute of Scientific and Industrial Research, Osaka University, (Kozaki et al., 2007)
2) Ontology Application Management (OAM), developed by the Language and Semantic Technology Laboratory, National Electronics and Computer Technology Center (NECTEC) (Buranarach, Thein, & Supnithi, 2013)
3) MySQL 5.0
4) Microsoft Access 2010

Methods

The methods of this study involve three main steps,

1) Verification of information need

2) Ontology development

3) Ontology evaluation

1. **Verification of information need**

This step involved a surveying and an identifying the scope and types of information needed by TTM-IS in answering questions recived from users. This was achieved by reviewing questionnaires filled by the staff of TTM-IS and in-depth interviews with the Thai traditional doctors at Chao Phya Abhaibhubejhr Hospital.

2. **Ontology development**

The methodology framework of ontology development. Is shown in Fig. 7

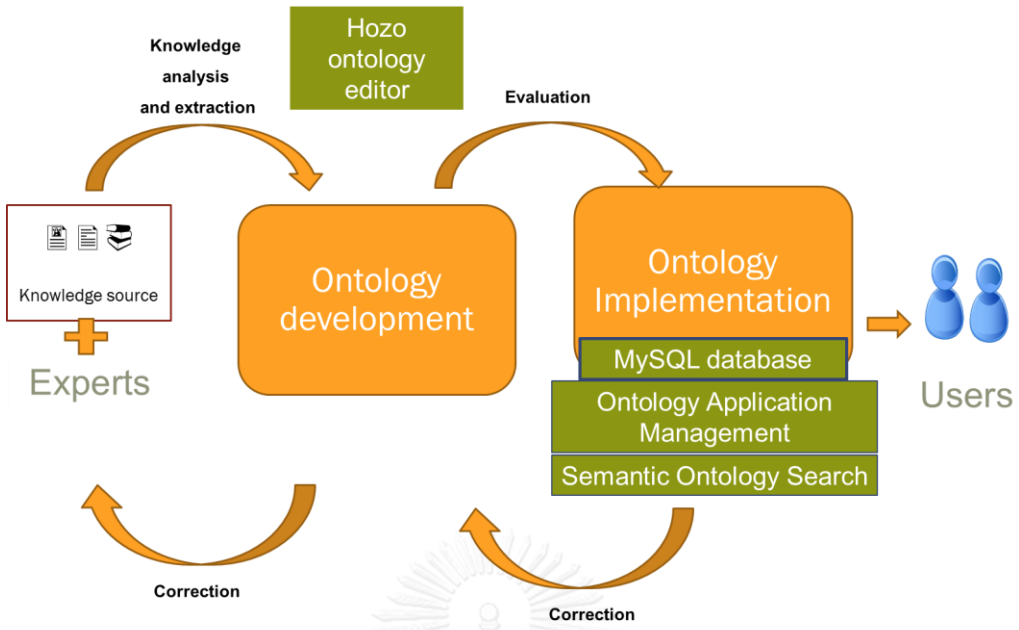


Figure 7 Ontology development framework

The ontology development consists of three steps: 1) knowledge analysis and extraction 2) ontology development and 3) ontology implementation. The first step involved analyzing and extracting knowledge from experts, documents and materials at Chao Phya Abhaibhubejhr Hospital.Triangulation was applied in the data collection, analysis and extraction process to ensure the creditability and conformability of the study. Concepts resulting from this step was then used in the ontology development process. The second focuses on developing the ontology schema by using Hozo Ontology Editor as an editing tool. The schema was subsequently evaluated by experts to ensure the conformability and validity before the implementation step. The third step involved database development by using Microsoft Access, MySQL database, and the ontology schema; and data base mapping by employing Ontology Application Management (OAM) and semantic

ontology search system. The resulting semantic search system enables users to browse information on herbal medicine.

The following sections describe ontology development and evaluation in detail.

2.1. Ontology development include the following steps:

2.1.1.**Extraction of relevant information on herbal medicine**

The scope of knowledge of Thai herbal medicine and information collection was defined, and The concepts regarding medicinal plants were formulated according to those found in *TamraPramuanLakPhesatchakam* (Watprachetuphol, 1978) and *WetchasuksaPhaetThayasatSangkhep: Manual for Student of Traditional Medicine by Phraya Phitsanuprasatwet* (*PhrayaPhitsanuprasatwet*, 1908). The concepts of illness/health problem and disease in TTM were extracted from *PhaetsartSongkroh: Medical Wisdom and National Literary Heritage* (Thai Language Institute, 1999) which has served as a key textbook on TTM containing a collection of *kamphi* or medical treatises officially endorsed by the Ministry of Public Health and widely used as reference sources on Thai traditional medicine. It contains theories of Thai traditional medicine and pharmacy regarding diagnosis, treatment methods, causes of illness, herbal medicine preparations, etc.

The numbers of herbal medicines according to the types of health problems included in this study are shown in Table 2. The scope of data collection was based on the types of health problems about which

questions are most frequently asked. The herbs and formulations in the database are from the drug lists of Chao Phya Abhaibhubejhr Hospital.

Table 2 Scope of data collection

Health problem	Herbs/ herbal remedies from the hospital drug list
Gastrointestinal system	5 herbs/ 6 remedies
Musculoskeletal system	2 herbs/ 4 remedies
Respiratory tract system	1 herbs/ 5 remedies
Diabetes	2 herbs/ 1 remedies
Fever	3 herbs/ 5 remedies
Total	**13 herbs/ 21 remedies**

2.1.2. Identification of concepts/classes

The concepts or classes of domain knowledge were enumerated for inclusion in the ontology. The knowledge domain in this study covers information of Herbal medicine-Herbs, Taste, Tri-That, Formulation, Indication, Preparation, Use Method and Clinical Warning. All these concepts are contained in the knowledge base and linked to the relevant information in answering queries by users.

2.1.3 Definition of the hierarchy of classes

This step involved assigning the superclasses or subclasses relationships of classes, which are represented in a hierarchical form. The

knowledge hierarchy model was created by using an ontology editing tool, Hozo Ontology Editor .

2.1.4 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. The object properties are used to describe the association of two related concepts/classes in ontology. It provides more information of the attached superclass. All the properties provide more information about the attached class.

2.1.5 Preparing the database on Thai herbal medicine

The ontology schema was then exported from Hozo Ontology Editor to the Ontology Web Language (OWL) (Smith, Welty, & McGuinness, 2009), a representation language which is used as a representation language of THMO. Meanwhile, the Thai herbal medicine database created with MS Access was exported to MySQL database server in order to prepare data for data mapping in the next step.

2.1.6 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 . 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 (RDF Working Group, 2007). 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.

3. Ontology evaluation

The evaluation of the ontology was conducted after the final schema of ontology had been completed. To test the validity of classes, subclasses, vocabularies and relationship identification in the ontology, experts from two professional groups, ontology engineers and Thai traditional doctors, were asked to fill out questionnaires to assess and make suggestions on the ontology schema. A focus group discussion was held specifically among the traditional doctors to achieve a consensus of opinion. At this meeting the contents of the ontology schema from the concepts, their relationships, the hierarchy of classes and subclasses were explained to them before they started the discussion and filled out the questionnaires afterward The ontology schema which was improved according to the experts' comments and suggests was to be used for the implementation step.

An 'expert' here is defined as those who has at least 3 years of work experience in his/her respective field and remains an active practitioner in that field. In all, eight experts, two ontology engineers and six Thai traditional doctors, were enlisted to assess the Thai traditional medicine ontology. Evaluation criteria consists of correctness of classes; subclasses; properties identification; reliable and reusability of the ontology.

Evaluation criteria

- **Correctness** refers to the degree to which the classes, subclasses and properties are properly defined with respect to the domain knowledge.

- **Consistency** refers to the degree to which there is no overlapping of the subclasses and sets of properties the ontology contains no classes which contain the same set of subclasses and no classes contain the same set of properties

- **Conciseness** refers to the degree to which the classes, properties and relationships in the ontology are relevant to the domain knowledge and included in the ontology map. No identical names must be assigned to different classes, and l irrelevant classes, properties and relationships must be excluded.

- **Future development and reusability** refers to the degree to which the ontology is reliable and reusable, and whether it can be applied to other domain knowledge.

Theme list questions are as follow:

1) Correctness

- Does the ontology capture the concepts of Thai herbal medicine correctly?
- Does the ontology capture the properties of Thai herbal medicine correctly?
- Does the ontology capture the relationships between classes/subclasses of Thai herbal medicine correctly?
- Does the ontology capture the data types? of Thai herbal medicine correctly?

2) Consistency

- Does the ontology include two or more concepts that share the same subclasses?
- Are there any circularity errors found in the ontology?
- Are there any inconsistencies of terms used in the ontology?

3) Conciseness

- Does the concepts in the ontology fall outside the frame of the domain knowledge?
- Does the properties in the ontologyfall outside the frame of the domain knowledge?

- Does the ontology capture the relationships between concepts outside the frame of domain knowledge correctly?

4) Future development and reusability

- Is the ontology reusable?
- Can the ontology be applied with further application or to other domain knowledge?

Data Analysis

Descriptive data analysis, mean and standard deviation were applied in calculating the experts' evaluation scores. The degree of the experts' opinion are classified as follows.

Remark	Score
Strongly agree	5
agree	4
Neutral	3
disagree	2
Strongly disagree	1

Trustworthiness of the study

This study has adopted a set of procedures to enhance the trustworthiness of its findings in the following aspects:

- To ensure creditability, triangulation was used in the extraction and conceptualization of data from various sources.

- To ensure conformability, triangulation was employed to validate data gathered from the focus group discussion and those from the questionnaires filled out by the experts during the ontology development process

- To ensure the transferability or reusability of the study, the ontology was evaluated by experts by using questionnaires.

Chapter IV

RESULT AND DISCUSSION

This Chapter covers the following topics:

1. Thai herbal medicine database
2. Thai herbal medicine ontology
3. Evaluation of ontology and semantic search system
   3.1. Ontology evaluation
   3.2. Semantic search system evaluation

1. Thai herbal medicine database

A Thai Herbal Database has been developed to store data on herbal medicine. The scope of data collection is described in chapter 1. Table 3 shows the data by different types of information in the database.

Table 3 data collection in Thai herbal database

Data contained in Database	Number of
List of plants	132
List of herb ingredients (include plant, animal and material	139
Herbal medicine and formulations	32
List of health problems/illness	24
List of indication	34

2. Thai herbal medicine ontology (THMO)

The knowledge base construction of Thai herbal medicine has been developed so called Thai herbal medicine ontology (THMO), contains 323 concepts which can be divided into three major components of ontology as follow:

2.1 Classes of Thai Herbal Medicine Ontology (THMO)

2.2 Object properties

2.3 Data properties

2.1 Classes of Thai Herbal Medicine Ontology (THMO)

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

1) **The Herb material class** represents the materials used for the medicinal purposes according to two of the official Thai traditional medical books, *TamraPramuanLakPhesatchakam* (ตำราประมวลหลักเภสัชกรรม) *(Watphrachetupol, 1978) and Wetchasuksa, phaetthayasatsangkhep* (เวชศาสตร์ศึกษา แพทยศาสตร์สังเขป)*: Manual for student of Thai traditional medicine* (Thai Language Institute, 1999). The main component of 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 Fig.8

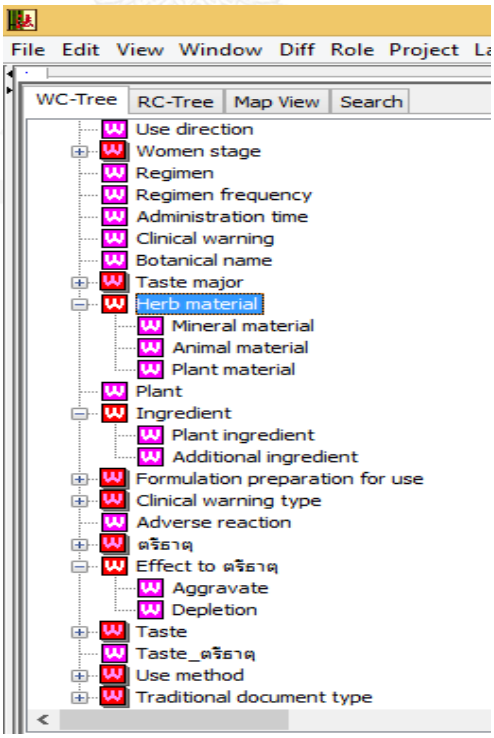


Figure 8 A Herb material class

2) **The Taste class** is defined according to the principle of Thai traditional pharmacy principle (Watphrachetupol, 1978) in which the tastes of herb are not merely sensation on the tongue but indicate their medicinal properties. When a traditional doctor prescribes herbs or makes herbal remedies for their patients, taste is one of th factors which they usually consider. Here tastes are classified according to two principles. The first divides tastes into three major sensations: hot, cool and su-khum (mild taste). The second classifies them into nine medicinal tastes: sour, sweet, astringent, bitter, salty, spicy, oily, maobua (เมาเบื่อ) and, mild and fragrant (หอมเย็น). The class hierarchy of tastes is shown in Fig.9

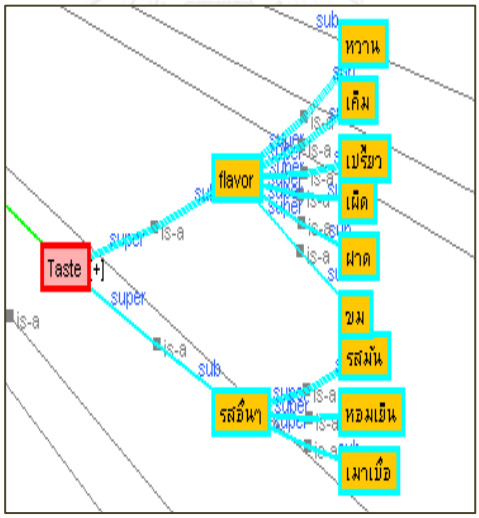


Figure 9 Hierarchy of Taste class

3) **The Tri-That (ตรีธาตุ) class** represents the concept of the 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 (Bamber, 1989). When the balance of these elements is disturbed, symptoms and illnesses will occur. The relationships between Taste and Tri-That are represented as 'aggravation' and 'depletion' properties.

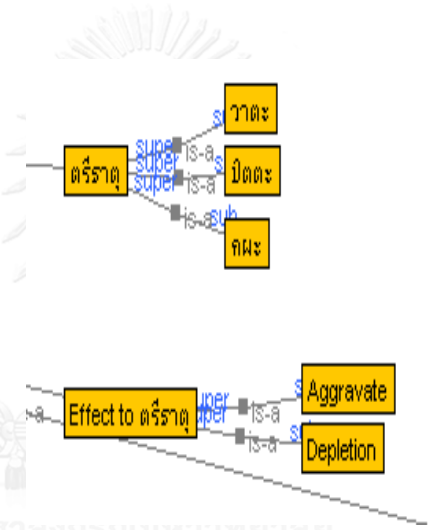


Figure 10 Tri That class and effect to Tri That class

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 reactions 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 Fig.11

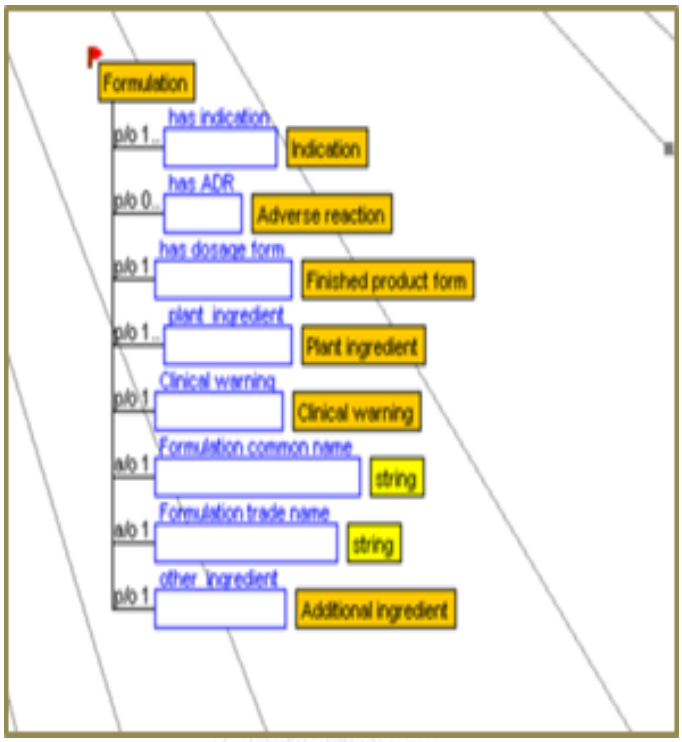


Figure 11 The Formulation class and *part-of* relationships

5) **The Use method class** conceptualizes the methods of administration covering all the route of herbs or herbal formulations are taken into the body as practiced in Thai traditional pharmacy and folk medicine. Although, Thai traditional pharmacy textbooks describe 23 methods of administration, other unusual methods including roasting, sudation, and body wrapping are practiced by folk doctors and people in communities around the country. These practices, though not officially recorded, are also included under this class. The conceptualized of all the method was achieved by a survey and interviews with traditional and folk medicine

practitioners conducted by Dr. Supaporn Pitiporn, Chao Phya Abhaibhubejhr Hospital Foundation [(Pitiporn, 2011), (Pitiporn, 2012) and (Pitiporn, 2014)]. The taxonomy of the Use Method is shown in Fig.12

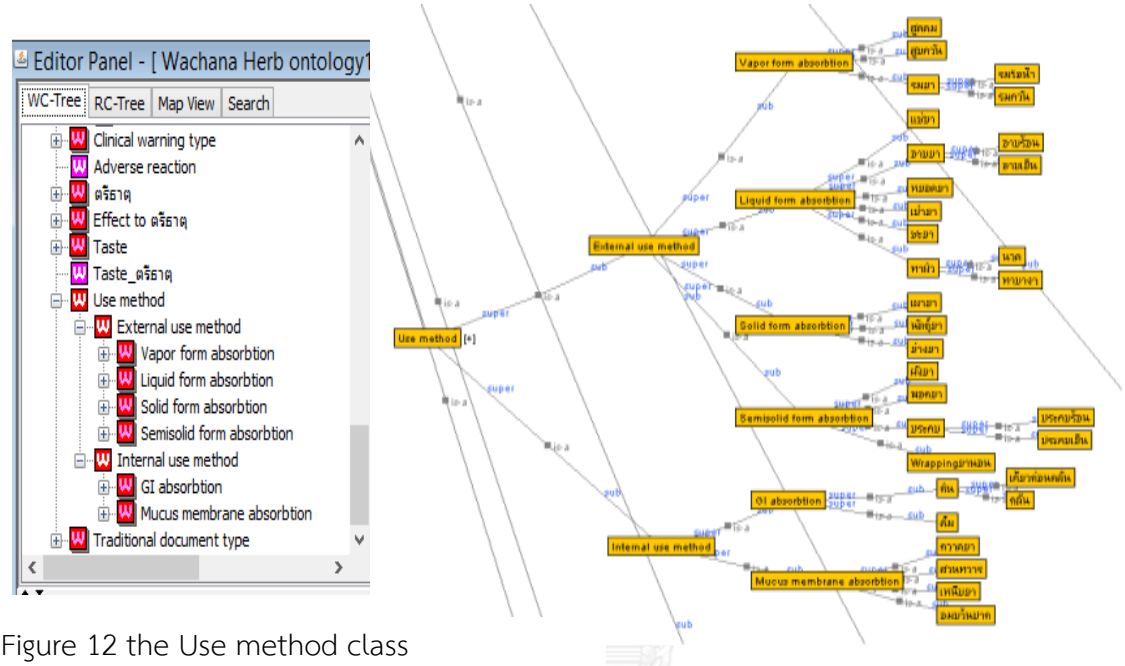


Figure 12 the Use method class

6) **The Health problem class** represents groups of health problems in accordance with Thai traditional medicine as well as the major systems of the body as described in convention medicine. 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 RokLom (โรคลม) are the common illnesses frequently mentioned in several textbooks and are conceptualized in this ontology. The

relationship between health problems and formulations are established by means of the Indication concept via the relationship of *hasHealthProblem*.

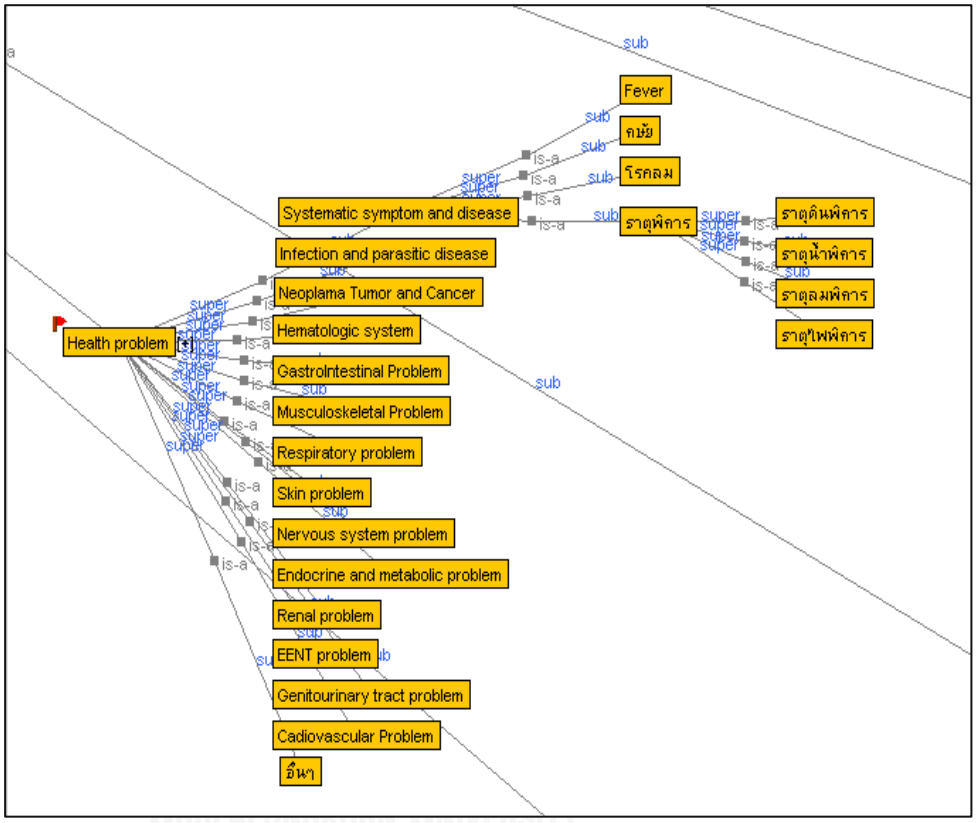


Figure 13 The Health problem hierarchy

7) **Indication class** represents the recommended uses of formulation for treating of health problems and, regimens of the formulas. Regimen class contains information of administration time and frequency of using the formulation.

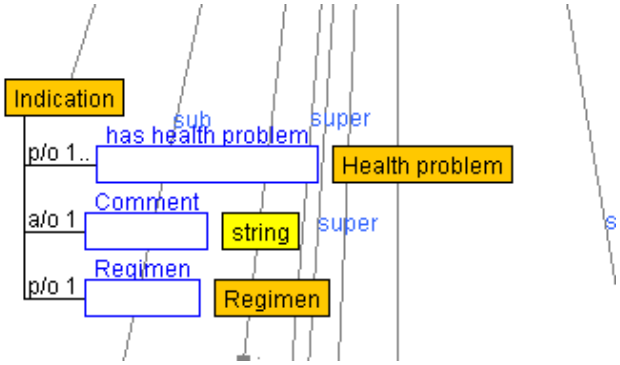


Figure 14 Indication class

8) **Finished Product Form class** represents the classification of the forms of herbal product used in Thai herbal medicine classified according to the physical form of products.

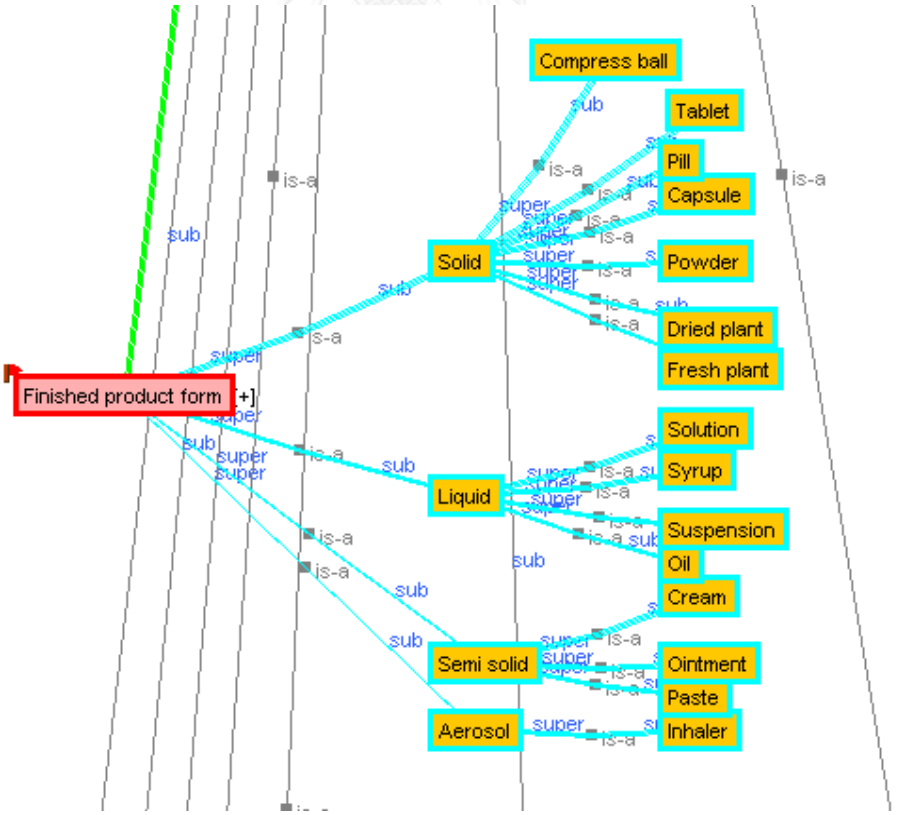


Figure 15 Finish Product Form class

9) **Formulation Preparation For Use** represents the methods of preparation of herbal medicine for use as shown in Fig.16. Some forms of finished products or dosage forms, such as dried herbs and fresh herbs, require preparation steps before administration. These preparation methods include those described in Thai traditional pharmacy textbooks as well as common preparation practices such as fermentation with sugar, salt or honey.

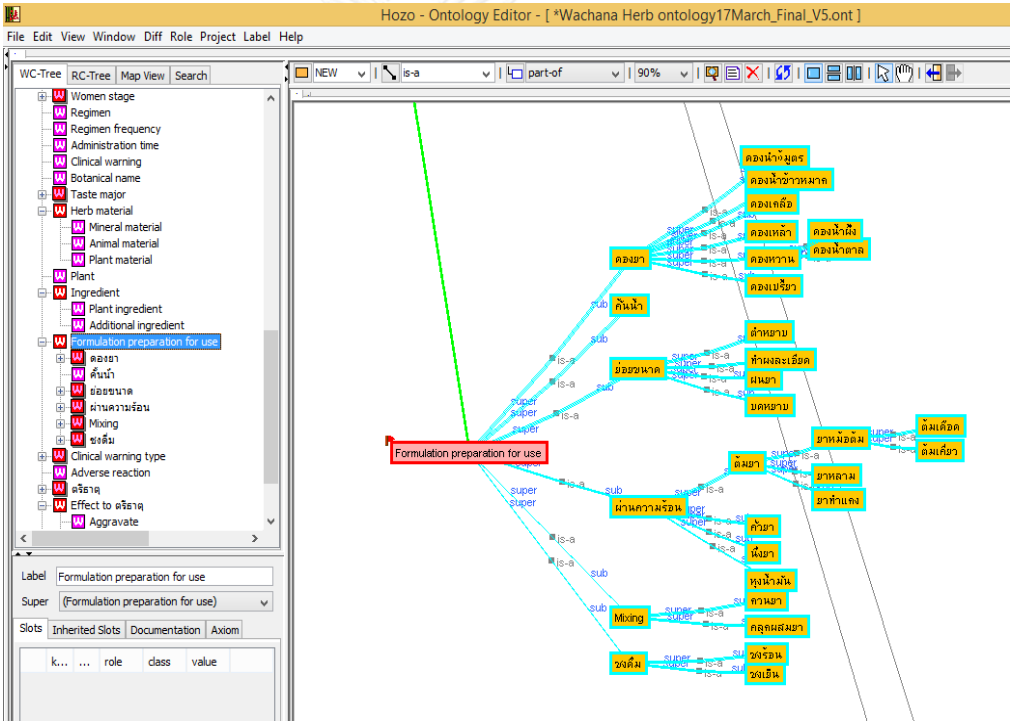


Figure 16 Formulation Preparation For Use

10) Plant Usage represents plant parts used in herbal formulations. Different part of the same plant may differ in medicinal properties or potency. Herb parts are classified according to plant morphology as shown in Fig. 17

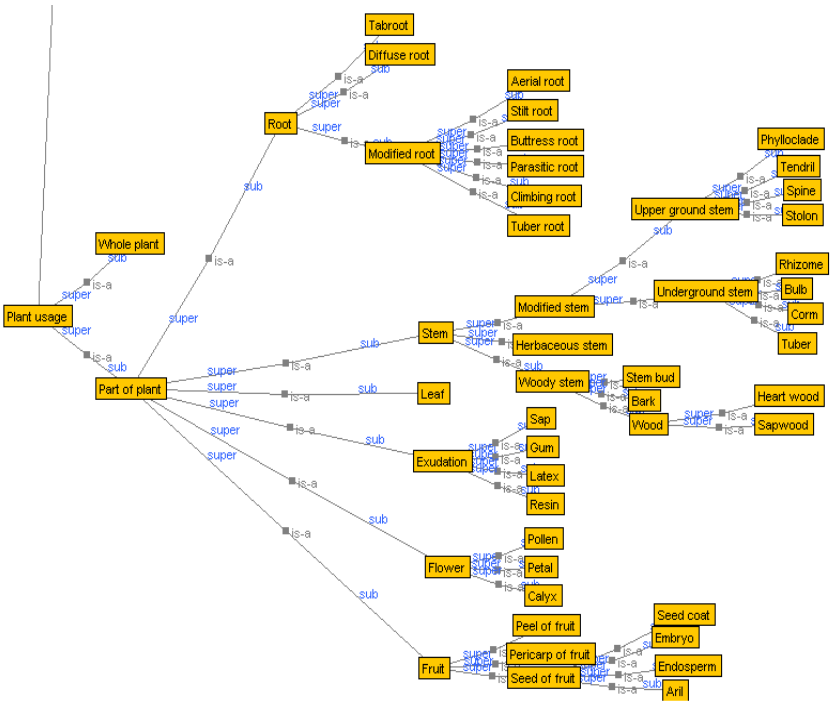


Figure 17 Plant Usage class

11) **Adverse reaction class** represents the adverse reactions associated with herbs or formulations. These are classified by severity into three sub-classes: mild, moderate and severe as shown in Fig.18

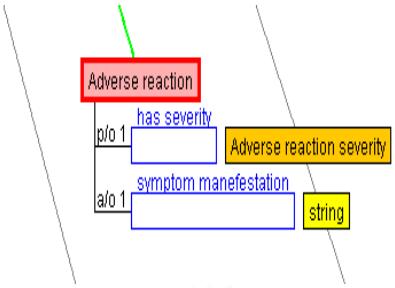


Figure 18 Adverse Reaction class

12) **Clinical Warning class** represents warnings for herbs or formulations including contraindication, precaution and other special conditions of user.

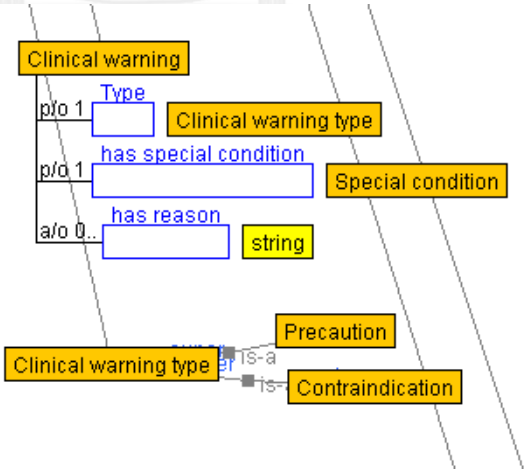


Figure 19 Clinical Warning class

13) **Special Condition class** represents cautions against using herbs or herbal formulations in certain grop of people and conditions or for certain period of time. These conditions include pregnancy stage, breastfeeding period, age and other medicines that might contraindicate with the herbs or formulations.

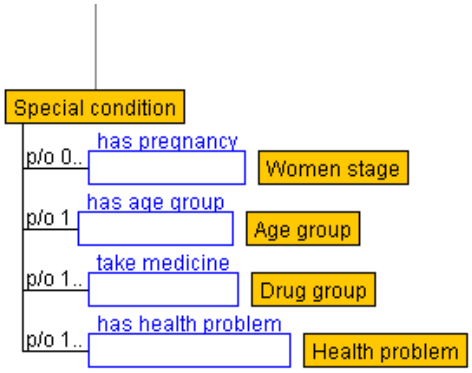


Figure 20 Special Condition Class

The list of major concepts as shown in Table 4

Table 4 THMO concept description

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

2.2 Object properties

Object properties indicates relationships between classes in the ontology. In THMO, object properties are described as shown in Table 5

Table 5 Objective properties description

	Object properties	Description
1	*hasPlant*	provides any of plant information which include plant botanical name, taste of plant and part of plant use as herb material
2	*HasBotanicalName*	Provide botanical name of plants
3	*hasTaste*	Provide taste information of plants
4	*hasTasteMajor*	Provide taste major of plants
5	*hasPartofPlant*	Relate Plant Material with Plant Usage. It describe part of plant which has medicinal properties
6	*hasTasteEffect*	Relate Taste with the Effect of Taste to Tri-That which can be describe in two type-aggravation and depletion
7	*hasIndication*	Relate the Formulation with the indication of the plant or formulation
8	*hasRegimen*	Describe the regimen of indication
9	*hasAdverseReaction*	Relate the Formulation with the Adverse reaction of formulation

	Object properties	Description
10	*hasDosageForm*	Relate the Formulation with the Dosage of the formulation of Thai tradition medicine
11	*hasClinicalWarning*	Relate the Formulation with the clinical warning of plant or the Formulation
12	*hasSpecialCondition*	Relate special condition with the Clinical Warning
13	*hasUseMethod*	Relate the Dosage form with the Use direction of the formulation
14	*HasAdministrationRoute*	Provide administration route information of each use method
15	*hasFormulationPreparation*	Relate the Use direction with the Formulation preparation of herbal medicine
16	*hasHealthProblem*	Provide health problem of indication
17	*hasPlantIngrdredient*	Provide plant ingredient in formulation
18	*hasPregnancy*	Provide pregnancy status with related to clinical warning
19	*hasAgeGroup*	Provide age group with related to clinical warning
20	*hasTakeMedicine*	Provide medicine which could have interaction with formulation in term of clinical warning

2.3 Data properties

The data type properties describes the value type of the classes which can be categorized including string, Boolean or number. 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 detail of data properties of THMO describe are shown in Table 6.

Table 6 Data properties description

	Data properties	Type of Data	Description
1	*Genus*	String	Text describe genus of plant
2	*Species*	String	Text describe species of plant
3	*Plant name Author*	String	Text describe author of plant
4	*Family*	String	Text describe family of plant
5	*Formulation common name*	String	Text describe the common name of the herbal formulation
6	*Amount*	Integer	Number indicate amount of herbal material use in the herbal formulation
7	*unit*	String	Text describe unit of herbal material use in the herbal formulation

	Data properties	Type of Data	Description
8	*Dose*	String	Text describe the dose of herbal medicine use for treatment of illness
9	*Comment*	String	Text describe
10	*Symptom manifestation (of adverse reaction)*	String	Text describe the adverse reaction symptom manifestation of
11	*Reason (of clinical warning)*	String	Text describe the reason of the clinical warning in terms of precaution and contraindication
12	*Instruction detail*	String	Text provide more information of use direction

3. Evaluation of ontology and sematic search system application

3.1 Evaluation of ontology

The final version of ontology was obtained after the ontology schema had been evaluated by experts to test the validity of concepts, classes, subclass, object properties and relationship identification. The evaluation scores are classified as shown in Table 7

Table 7 Experts evaluation scores

Corresponding remark	Score
Strongly agree	4.50-5.00
Agree	3.50-4.49
Neutral	2.50-3.49
Disagree	1.50-2.29
Strongly agree	1.00-1.49

Two groups of experts were asked to evaluate the ontology in the following aspect:

1) validity of scope determination

2) validity of class identification

3) validity of property identification

4) Future development and reusability

3.1.1 Experts opinion on proper of scope determination

Table 8 Scope determiation evaluation

Evaluation of scope determination	Ontology experts		Traditional Doctors	
	$\bar{X}$	SD	$\bar{X}$	SD
The scope match with the information need of TTM-IS	4.50	0.71	4.33	0.47
The scope appropriate to the knowledge domain	4.50	0.71	3.83	0.37
The scope can be applied with the search system of TTM-IS	4.50	0.71	4.50	0.50
The concepts used are reasonable	4.00	0.00	4.33	0.75
The superclass is appropriate to the scope	4.50	0.71	3.83	0.37
Total	4.40	0.32	4.17	0.49
Overall satisfaction	$\bar{X}$=4.29, SD =0.48			

As shown in Table 8, all the experts agreed with the scope determination of Thai herbal medicine ontology. The total average score is 4.29 with a standard deviation of 0.48.

3.1.2 Experts opinion on class identification

Table 9 Class identification evaluation

Evaluation of class identification	Ontology experts		Traditional Doctors	
	$\bar{X}$	SD	$\bar{X}$	SD
Subclasses identification are correct	3.50	0.71	3.83	0.69
The type of data properties are correct	4.00	0.00	4.83	0.37
Terminology used in ontology are appropriate	4.00	0.00	4.17	0.37
Values constraint of ontology are correct and appropriate	4.00	1.41	4.33	0.47
Total	3.88	0.53	4.29	0.48
Overall satisfaction	$\bar{X}$=4.09, SD =0.51			

As shown in Table 9, all the experts agreed with the identification of classes and subclasses. The total average score is 4.09 with standard deviation of 0.51. The experts also agreed with the identification of data properties, terms used in ontology and the value constraint of the ontology.

3.1.3 Experts opinion on property identification

Table 10 Properties identification evaluation

Evaluation of property identification	Ontology experts		Traditional Doctors	
	$\bar{X}$	SD	$\bar{X}$	SD
Properties defined are related to concepts	4.50	0.71	4.17	0.69
Relationships defined for each concept is correct	4.50	0.71	4.50	0.50
Relationships have no constraint	4.00	0.00	4.50	0.50
Total	4.33	0.47	4.39	0.56
Overall satisfaction	$\bar{X}$=4.36, SD =0.52			

As shown in Table 10, all the experts agreed with property identification. The total average score is 4.36 with standard deviation of 0.52. They also agreed with relationship identification and that all relationships have no constraint.

3.1.4 Expert opinion of future development and reusability of Thai herbal medicine ontology

Table 11 Future development and reusability evaluation

Evaluation of future development and reusability	Ontology experts		Traditional Doctors	
	$\bar{X}$	SD	$\bar{X}$	SD
The ontology is reliable	4.50	0.71	4.50	0.50
The ontology can be reused and applied with other medical ontology	4.50	0.71	4.67	0.47
Total	4.50	0.71	4.58	0.49
Overall satisfaction	$\bar{X}$=4.54, SD =0.60			

As shown in Table 11, the all experts strongly agreed with future development and reusability of the ontology. The total average score is 4.54 with a standard deviation of 0.61.

3.2 Semantic search system function

This section presents an implementation of prototype of semantic search to discover relationship concepts in user query and to perform search process by using user concepts. The Semantic Ontology Search (SOS), a sematic search system application which was developed by NECTEC, was used as a user interface to perform querying and searching for herbal medicine information. The system allows users to select the searching criteria either by concepts-based query or keyword-base query.

Figure 21 Sematic Ontology Search application initial screen

The information source is a MySQL database which was developed exclusively for this study, covering diseases and herbal medicines as mentioned in chapter 3.

The initial search screen has shown in Fig.21. To start a search, the user would choose the desired concepts or that related to the question. For example, to query for herbs/formulations to treat fever, the user can select Formulation in the drop down box, choose Health Problem and then Fever respectively. The user can select other health problems in the same manner, and the system will start searching automatically. The search screen is shown in Fig.22

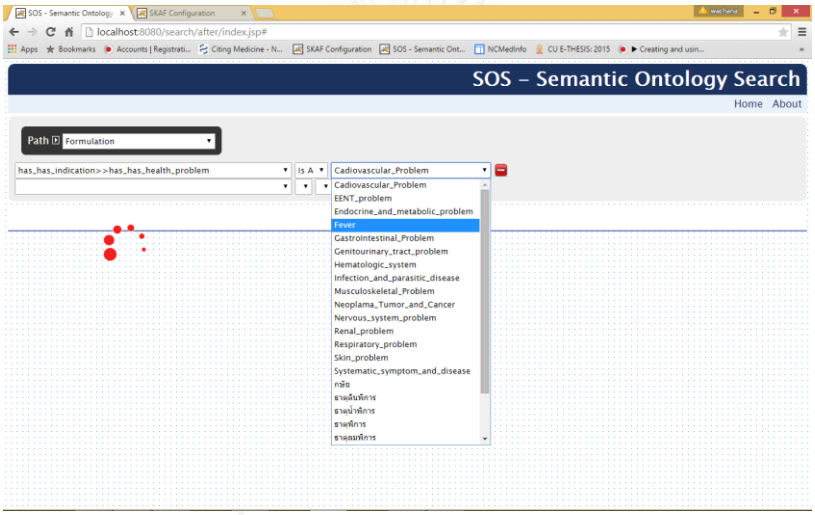


Figure 22 Searching screen from Semantic Ontology Search

The efficiency of the sematic search system application has not been applied in this study. This step can be perform in the future study to proof the ability of the semantic ontology search (SOS) in retrieving correct answer in the scope of the ontology for TTM-IS. This study recommend the use of frequently asked question which retrieved by TTM-IS to design the scenarios for evaluation the performance of the system according to the precision and coverage criteria suggested in Chapter 2. The scenario questions for testing the performance of THMO are shown in Table 12.

Table 12 Scenarion questions

Scenario	Questions	Related concepts in THMO
1	What is herbal formulation to treat health problems include: - Fever - Musculoskeletal problem - Gastrointestinal problem - Respiratory tract problem - Diabetes	Formulation, Health problem
2	Which herbs/ herbal formulations cannot use during pregnancy?	Clinical warning, Women stage
3	Which herbs/ herbal formulations cannot use during breast feeding?	Clinical warning, Women stage
4	What are the ingredients of herbal formulations such as: - Pet sang kat - Ya-kae-ammapreuk-ammapart (ยาแก้อัมพฤกษ์อัมพาต) - Pra-sa-ka-prao(ประสะกะเพรา)	Formulation, Plant Ingredient
5	Which are hot taste herbs?	Plant, Taste

Scenario	Questions	Related concepts in THMO
6	What are the adverse reactions of hers/herbal formulation? such as: - Bitter cucumber (มะระขี้นก) - Ginger - Thao wan prieng (เถาวัลย์เปรียง) - Sa hat thara (สหัสธารา)	Formulation, Adverse reaction
7	What are the herbs/herbal formulations should be careful while taking warfarin?	Formulation, Clinical warning
8	Which are herbs/herbal formulations for treatment of fever in children?	Formulation, Indication, Regimen, Health problem
9	What is a regimen of Turmeric for treatment of flatulence?	Indication, Regimen
10	Which are herbs/ herbal formulations can be prepared byboiling method?	Finished product form

Chapter V

CONCLUSION

This study has developed a Thai Herbal Medicine Ontology that conceptualizes the formal domain knowledge of herbal medicine in order to support the consultation services provided by Thai Traditional Medicine Information Service (TTM-IS) regarding information search and retrieval. The Thai Herbal Medicine Ontology (THMO) has been developed, featuring the practices and theories of Thai traditional medicine as well as Thai folk remedies. It is intended to be a reference model of Thai traditional medicine knowledge. This semantic search application can assist the work of healthcare professionals at TTM-IS with respect to information search by means of a concept-based search system.

Contributions of the study

This study hopes the development of this ontology-based search system would o make significant contribution to the advancement and utilization of Thai herbal medicine in a few ways. First, it has constructed a taxonomy of concepts that would greatly enhance knowledge and understanding of Thai traditional medicine and provide a valuable tool for search systems in this field. The utilization of ontology techniques to identify key concepts and relationships among concepts in Thai herbal medicine has created an explicit form of this domain knowledge. The ontology, which has been validated and tested for credibility, conformability,

transferability and reusability, holds potential for building upon or linking to related ontologies in the future.

Second, this study has developed a MySQL-based database of Thai herbal medicine. When integrated with the ontology, this database has created a knowledge base in the RDF (Resource Description Framework) format, using OAM, an ontology mapping tool.

Third, this study has adopted the OAM semantic search application template in order to create a semantic search system with a user interface that will be a prototype for other ontology-based search systems on Thai traditional medicine and herbal remedies. .

Limitations of the study

1. The Sematic Ontology Search (SOS) is a prototype of search system developed to demonstrate the usefulness of an ontology of Thai herbal medicine ontology in support information search on the subject. . Although, the concept-based search can retrieve precise and coverage answers for the end user. the search process may still be too complicated for general users compared to search engine such as Google or Yahoo with which they can just type keywords for a search. By contrast, to be able to use SOS effectively, the user must understand which concepts represent the key words about which they want to know. Therefore, any users of this search system should be trained in the ontology schema and system function to attain accurate search results. The user interface which is available and used to develop the sematic search system in this study is designed for general purposes rather than for specified fields of knowledge such

as Thai herbal medicine. Consequently, information display of search results such as formulation ingredients, indications or clinical warnings are not user-friendly as it is difficult to read and not attractive. This expected to be improved in the new version of semantic ontology search.

2. To make this study manageable, information in the database is representative rather than comprehensive. It covers only 133 plants and 23 formulations. A vast amount of data must be added in the database in the future if TTM-IS are to take full advantage of this search system

3. Large volume of data may slow down the search speed of the current version of SOS. The efficiency of search with THMO would benefit from improvements in its next version.

Future development

To further develop THMO into a truly comprehensive application, the ontology of Thai herbal medicine needs to be expanded in its depth and breadth. For example, to increase the depth, the hierarchy of health problems should be extended by adding more subclasses conceptualized from a much wider range of illnesses and diseases. . This, however, is contingent upon a systematic classification of diseases according to Thai traditional medical theories, which is not yet available. Therefore, high priority should be given to research to build such a taxonomy of diseases.

While a larger number of experts in herbal medicine should be involved to refine the ontology, the participation of experts from other related fields, specifically

Thai traditional medicine would broaden its scope, establishing links between THMO and other domains of knowledge such as medical knowledge, plant pharmacology, plant phytochemistry or ethno-botany. Furthermore, it could be branched out into other useful information systems such as a herbal medicine literature search system, a recommendation system and decision support applications.

Finally, further development of THMO should concern terminology standardization and evaluation of its efficiency as an informational retrieval model in terms of precision, recall and/or F-measure.

รายการอ้างอิง

Bamber, S. (1989). *An Examination of the Classification and Treatment of Illness in Traditional Thai Medicine.* Australian National University, place unknown.

Brewster, C., & O'Hara, K. (2007). knowledge representation with ontologies:present challenges-future possibilities. *Int. J. Human-compuer studies, 65*, 563.

Buranarach, M., Thein, Y., & Supnithi, T. (2013). A Community-Driven Approach to Development of an Ontology-Based Application Management Framework. In H. Takeda, Y. Qu, R. Mizoguchi & Y. Kitamura (Eds.), *Semantic Technology* (Vol. 7774, pp. 306-312): Springer Berlin Heidelberg.

Calegari, S., & Pasi, G. (2010). Ontology-based Information Behavior to Imporve Web Search. 2014, from www.mdpi.com/journal/futureinternet

Chokevivat, V., Chutaputti, A., & Khumtrakul, P. (2005). *The Use of Traditional Medicine in the Thai Health Care System.* Paper presented at the Regional Consultation on Development of Traditional Medicine in the South East Asia Region, Pyongyang,Korea.

Chokevivat, V., Wibulpolprasert, S., & Petrakard, P. (2012). *Thai Traditional and Alternative Health Profile: Thai Traditional Medicine, Indigenous Medicine and Alternative Medicine 2009-2013*. Bangkok: WVO office of printing mill.

Gu, P. (2010). Causual Knowledge Modeling for Traditional Chinese Medicine Using OWL 2. Retrieved 15 Dec, 2014, from http://iswc2010.semanticweb.org/pdf/432.pdf

Hoehndorf, R., Dumontier, M., & Gkoutos, G. (2012). Evaluation of Research in Biomedical Ontologies. Retrieved 2 Nov, 2014, from http://bib.oxfordjournals.org

Kamsu-Foguem, B., Diallo, G., & Forum, C. (2012). Conceptual Graph-Based Knowledge Representation for Supporting Reasoning in African Traditional Medicine. *Engineering Applications of Artificial Intelligence*.

Khan, L. R. (2000). *Ontology-based Information Selection.* University of South California.

Kozaki, K., Sunagawa, E., Kitamura, Y., & Mizoguchi, R. (2007). Distributed Construction of Ontologies Using Hozo. 2007, from http://www.www2007.org/workshops/paper_19.pdf

Kuziemsky, C., & Lau, F. (2010). A Four State Approadh for Ontology-based Health Information System Design. *Artificial Intelligence in Medicine, 50*, 133-148.

Musen, M. (2000). Protege. Retrieved from http://protege.stanford.edu/

Nantiruj, T., Maneerat, N., Varakulsiripunth, R., Izumi, S., & Shiratori, N. (2008). *An Health Advice System with Thai Herb and an Ontology*. Paper presented at the The Third International Symposium of Biomedical Engineering, Bangkok, Thailand.

Noy, N. F., & McGuinness, D. L. (2001). *Ontology Development 101 : A Guide to Creating Your First Ontology*. Knowledge System Laboratory 01.

Oladosu, J. B., Align, M. O., & Mbarika, V. (2012). *Towards a Pharmaceutical Ontology for African Traditional Herbs.* Paper presented at the The World Congress on Engineering and Computer Science, United State of America.

Pitiporn, S. (2011). *Bantuekphaendin 4-Samunprai Ya kamlang* (1 ed.). Bangkok: Praramath printing.

Pitiporn, S. (2012). *Bantuekphaendin 5-Samunprai Prakob Ob Arb Nuad* (1 ed.). Bangkok: Praramath printing.

Pitiporn, S. (2014). *Bantuekphaendin 7-Samunprai Du Lae Mae Ying* (1 ed.). Bangkok: Praramath printing.

Prakittikornchai, S. (2007). *Thai Herb Ontology Prototyping.* King Mongkut's University of Technollgy North Bangkok.

RDF Working Group. (2007, 2015/05/10/12:24:53). RDF - Semantic Web Standards. *W3C semantic web.* 2014, from http://www.w3.org/RDF/

files/14/RDF.html

Riano, D., Real, F., Lopez-Vallerdu, J. A., Campana, F., & Recline, S. (2012). An Ontology-Based Personalization of Health Care Knowledge to Support Clinical Decisions for Chronically Ill Patients. *Journal of Biomedical Informatics, 45*, 429-446.

Sakthi Priya, T., Revathy, P., Pradeesh, T., & Rene Robin, C. R. (2012). Design and Development of an Ontology Based Personal Web Search Engine. *Procedia Technology, 6*, 299-306.

Siricharoen, W. V. (2009). Ontiology Modeling and Object Modeling in Software Engineering. *International Jouranl of Software Engineering and Its Application, 3*(1), 43-59.

Smith, M. K., Welty, C., & McGuinness, D. L. (2009, 2009/11/12/

2015/05/10/12:33:20). OWL Web Ontology Language Guide. *W3C.* from http://www.w3.org/TR/owl-guide/

files/16/owl-guide.html

Thai Language Institute. (1999). *Phaetsart Songkroh: Medical Wisdom and National Literary Heritage* (แพทย์ศาสตร์สงเคราะห์: ภูมิปัญญาทางการแพทย์และมรดกทางวัฒนธรรมของชาติ (Bangkok: องค์การค้าครุสภา.

Vadivu, G., & Hopper, W. S. (2012). Ontology Mapping of Indian Medicinal Plants with Standardized Medical Terms. *Journal of Computer Sciences, 8*(9), 1576-1584.

Wang, W., Mao, H., Dai, W., & Sun, Y. (2010). *Technological Resource Search Engine Based on Ontology.* Paper presented at the The Third International Symposium on Electronic Commerce and Security Workshops, China.

Watphrachetupol. (1978). Tamra Pramuan Lak Phesatchakam (ตำราประมวลหลักเภสัชกรรม) (pp. 207). Bangkok: Phaisalsilp karnphim.

WHO. (2002). WHO Traditional Medicine Strategy 2002-2005 (pp. 61): World Health Organization.

Yu, A. C. (2006). Methods in Biomedical Ontology. *Journal of Biomedical Informatics, 39*, 252-266.

Yu, J., Thom, J. A., & Tam, A. (2009). Requirements-Oriented Methodology for Evaluation Ontologies. *Information System, 34*, 766-791.

Zhang, X., & Robinson, M. (2011). The World Medicines Situation 2011 Traditional Medicines: Global situation ,Issues and Challenges. In W. H. Organization (Ed.): World Health Organization.

ภาคผนวก

แบบประเมินเพื่อการวิจัย

เรื่อง การพัฒนาออนโทโลยีสมุนไพรของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร

.....

คำชี้แจง

แบบประเมินชุดนี้เป็นแบบสอบถามความคิดเห็นเกี่ยวกับต้นแบบออนโทโลยีสมุนไพรไทยที่เป็นต้นแบบของการพัฒนาระบบสืบค้นข้อมูลสมุนไพรของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร ออนโทโลยีที่พัฒนาขึ้นเพื่อใช้เป็นต้นแบบของพัฒนาระบบสืบค้นและการจัดการความรู้ที่สอดคล้องกับการทำงานของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทย โดยความเห็นของผู้เชี่ยวชาญจะช่วยพัฒนาให้โครงสร้างออนโทโลยีมีความถูกต้อง สมบูรณ์ และนำไปพัฒนาต่อยอดได้ต่อไป

วัตถุประสงค์ของแบบสอบถาม

1. เพื่อประเมินโครงสร้างออนโทโลยีสมุนไพรไทยของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร
2. เพื่อนำผลการประเมินโครงสร้างออนโทโลยี และข้อเสนอแนะจากผู้เชี่ยวชาญมาประยุกต์ใช้ในการพัฒนาระบบสืบค้นและการจัดการความรู้ที่สอดคล้องกับการทำงานของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร

คำชี้แจงในการตอบแบบประเมิน

1. แบบสอบถามมีทั้งหมด 3 ตอน ประกอบด้วย
   ตอนที่ 1. ข้อมูลสถานภาพส่วนบุคคล
   ตอนที่ 2. ข้อมูลการประเมินโครงสร้างออนโทโลยี
   ตอนที่ 3. ข้อเสนอแนะเพิ่มเติม
2. แบบสอบถามเป็นส่วนหนึ่งของการศึกษาวิจัยเรื่องการพัฒนาออนโทโลยีสมุนไพรของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของโรงพยาบาลเจ้าพระยาอภัยภูเบศร
3. โปรดตอบแบบสอบถามทุกข้อตามความเป็นจริง และข้อมูลของท่านจะเป็นความลับ

ผู้วิจัยขอขอบคุณผู้เชี่ยวชาญทุกท่าน ที่ให้ความร่วมมือในการตอบแบบสอบถามมา ณ โอกาสนี้

(นางวัจนา ตั้งความเพียร)

นิสิตระดับบัณฑิตศึกษา สาขาวิชาเภสัชศาสตร์สังคมและการบริหาร
คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

……

ตอนที่ 1 แบบสอบถามสถานภาพส่วนบุคคล

<u>คำชี้แจง</u> โปรดระบุข้อมูลสถานภาพของท่านลงในช่องว่าง

1.1 ชื่อ ……

นามสกุล……

1.2 ระดับการศึกษา ……

สาขา…… มหาวิทยาลัย/สถาบันที่สำเร็จการศึกษา……

1.3 สถานที่ทำงาน……

……

……..

……

……..

1.4 ตำแหน่ง……

……

1.5 ความรู้/ความชำนาญของท่าน (ตอบได้มากกว่า 1 ข้อ)

☐ ผู้เชี่ยวชาญด้านวิศวกรรมความรู้ ☐ ผู้เชี่ยวชาญด้านSemantic web

☐ ผู้เชี่ยวชาญด้านการออกแบบและพัฒนาออนโทโลยี ☐ นักสารสนเทศ

☐ นักวิชาการ/นักวิจัย ☐ อื่นๆ

ในกรณีเลือกอื่น ๆ โปรดระบุ……

……

1.6 ประสบการณ์ทำงาน ……ปี

1.7 สถานที่ติดต่อที่ท่านสะดวก……

……

……Tel……

……

1.8 E-mail :

……

ตอนที่ 2 แบบสอบถามด้านการออกแบบโครงสร้างออนโทโลยี

<u>คำชี้แจง</u> กรุณาทำเครื่องหมาย √ ลงในช่องว่างที่ตรงกับระดับความคิดเห็นของท่านมากที่สุดเพียงข้อเดียว โปรดตอบทุกข้อ

ระดับความคิดเห็นมากที่สุด(5) หมายถึง ข้อความตรงกับความคิดเห็นระดับมากที่สุด

ระดับความคิดเห็นมาก(4) หมายถึง ข้อความตรงกับความคิดเห็นระดับมาก

ระดับความคิดเห็นปานกลาง(3) หมายถึง ข้อความตรงกับความคิดเห็นระดับปานกลาง

ระดับความคิดเห็นน้อย(2) หมายถึง ข้อความตรงกับความคิดเห็นระดับน้อย

ระดับความคิดเห็นน้อยที่สุด(1) หมายถึง ข้อความตรงกับความคิดเห็นระดับน้อยที่สุด

คำชี้แจงอธิบายความหมายและขอบเขตการศึกษาวิจัย

1. สมุนไพร หมายถึง ผลิตภัณฑ์ธรรมชาติที่ได้จากพืช สัตว์ หรือแร่ธาตุซึ่งนำมาใช้ทำยาได้ หรือใช้ผสมกันตามตำรับยาเพื่อบำบัดโรคหรือบำรุงร่างกาย

2. ออนโทโลยี (Ontology) หมายถึง การบรรยายแนวคิด หรือขอบเขต(Concepts) ของสิ่งที่สนใจ สามารถแสดงโดยคำศัพท์ (Vocabulary) และประโยค (Sentence) โดยการกำหนดคุณสมบัติ (Property) ที่เกี่ยวข้องกับแนวคิด และลักษณะความสัมพันธ์ (Relationships) รวมทั้งตรรกะของความสัมพันธ์ต่าง ๆ เพื่อการสร้างความหมาย (Tom Gruber, 2007)

3. คอนเซพท์ (Concept) หมายถึง แนวคิดในขอบเขตที่สนใจ คือสมุนไพรไทยที่จะใช้เพื่อการสืบค้นของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทย รพ.เจ้าพระยาอภัยภูเบศร

4. คุณสมบัติ (Properties) หมายถึง คุณสมบัติต่าง ๆ ที่มีความเกี่ยวข้องสัมพันธ์กันกับแนวคิด (Concepts) เพื่อใช้ในการอธิบายแนวคิดทั้งหมด

5. ความสัมพันธ์ (Relationship) หมายถึง การนำเสนอความสัมพันธ์ระหว่างแนวคิดกับแนวคิดในขอบเขตที่สนใจ

6. ค่าอินสแตนซ์ (Instance) หมายถึง คำศัพท์ต่างๆ ที่มีการกำหนดนิยามความหมายภายในออนโทโลยี

ข้อ	ประเด็นข้อคำถาม	ระดับความคิดเห็น					ข้อเสนอแนะ
		มากที่สุด (5)	มาก (4)	ปานกลาง 3)	น้อย (2)	น้อยที่สุด(1)	
กระบวนการระบุขอบเขตและวัตถุประสงค์ของการพัฒนา (Determine Scope)							
1.	อ อ น โ ท โ ล ยี (Ontology) ที่ออกแบบพัฒนามีความสอดคล้องกับขอบเขต(Domain) สมุนไพรของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของรพ.เจ้าพระยาอภัยภูเบศร						
2.	ออนโทโลยีที่ออกแบบพัฒนามีความเหมาะสมของข้อมูลกับขอบเขต(Domain) สมุนไพรไทย						
3.	ออนโทโลยีที่ออกแบบพัฒนามีความเหมาะสมที่สามารถนำไปใช้ประยุกต์ในระบบสืบค้นข้อมูลของศูนย์ข้อมูลข่าวสารการแพทย์แผนไทยของรพ.เจ้าพระยาอภัยภูเบศร						
กระบวนการกำหนดคลาสหรือคอนเซพท์ของโดเมนที่สนใจ (Define Classes)							
4.	ออนโทโลยีที่ออกแบบพัฒนามีความเหมาะสมในการกำหนดแนวคิด(Concepts) ที่สามารถอธิบายรายละเอียดข้อมูลได้อย่างมีเหตุผล						
5.	ออนโทโลยีมีการจัดแบ่งคลาสเฉพาะ (Super-class) ได้อย่างถูกต้องเหมาะสม						

ข้อ	ประเด็นข้อคำถาม	ระดับความคิดเห็น					ข้อเสนอแนะ
		มากที่สุด (5)	มาก (4)	ปานกลาง 3)	น้อย (2)	น้อยที่สุด(1)	
กระบวนการกำหนดคลาสหรือคอนเซพท์ของโดเมนที่สนใจ (Define Classes)							
6.	ออนโทโลยีมีการจัดแบ่งคลาสย่อย(Subclass) ได้อย่างถูกต้องเหมาะสม						
7.	ออนโทโลยีที่ออกแบบพัฒนามีการกำหนดประเภทของข้อมูล (data type) ที่ถูกต้องและเหมาะสม						
8.	ออนโทโลยีที่ออกแบบพัฒนามีการกำหนดคำศัพท์(Term)ได้อย่างเหมาะสม						
9.	ออนโทโลยีที่ออกแบบพัฒนามีการกำหนดค่าของข้อมูลที่สามารถใช้ได้ (values constraint) ได้สอดคล้องและเหมาะสม						
กระบวนการกำหนดคุณสมบัติของคลาส (Define Properties)							
10.	ออนโทโลยีที่ออกแบบพัฒนามีการกำหนดคุณสมบัติต่างๆ (Properties) ที่เกี่ยวข้องสัมพันธ์กับแนวคิดสามารถใช้ในการอธิบายแนวคิดได้อย่างถูกต้องและชัดเจน						
11.	ออนโทโลยีที่ออกแบบพัฒนามีความเหมาะสมของความสัมพันธ์ (Relationships) ระหว่างแนวคิดในขอบเขตที่สนใจแบบความสัมพันธ์ที่เกี่ยวข้องได้อย่างเหมาะสม						

ข้อ	ประเด็นข้อคำถาม	ระดับความคิดเห็น					ข้อเสนอแนะ
		มากที่สุด (5)	มาก (4)	ปานกลาง 3)	น้อย (2)	น้อยที่สุด(1)	
กระบวนการกำหนดคุณสมบัติของคลาส (Define Properties) (ต่อ)							
12.	ออนโทโลยีที่ออกแบบพัฒนามีรูปแบบความสัมพันธ์ที่เหมาะสมและไม่ขัดแย้งกัน						
การประยุกต์ใช้และการพัฒนาโครงสร้างออนโทโลยีในอนาคต							
13.	โครงสร้างออนโทโลยีที่ออกแบบพัฒนามีความถูกต้องและน่าเชื่อถือ						
14.	ออนโทโลยีที่ออกแบบพัฒนามีความสามารถในการประยุกต์ใช้เพื่อการพัฒนาระบบอื่นๆ (Reused) ที่เกี่ยวข้องกับโดเมนระบบการแพทย์แผนไทยหรือแผนปัจจุบันได้						

ตอนที่ 3 ข้อเสนอแนะเพิ่มเติม

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

List of Experts

Thai traditional experts

1.	Supaporn Pitipoirn, Ph.d.	Chao Phya Abhaibhubejhr Hospital
2.	Miss Prangthip U-sa	Chao Phya Abhaibhubejhr Hospital
3.	Miss Chantima Suwan	Chao Phya Abhaibhubejhr Hospital
4.	Miss Areewan Thonthapthai	Chao Phya Abhaibhubejhr Hospital
5.	Miss Natcha Tengtermwong	Chao Phya Abhaibhubejhr Hospital
6.	Miss Chalalai Chokedeesrichan	Chao Phya Abhaibhubejhr Hospital

Ontology engineering experts

7.	Dr. Nopadol Chalortham	Pharmaceutical Science, Chiang Mai University
8.	Mr. Taneth Ruangrajitpakorn	Language and Semantic Technology Laboratory, National Electronics and Computer Technology Center (NECTEC)

ประวัติผู้เขียนวิทยานิพนธ์

My name is Wachana Tungkwampian.I was born in Bangkok, on January 1, 1979. I was received bachelor degree in Pharmaceutical Science from Chulalongkorn University on year 2000. I started working as a pharmacist at Bansang Hospital, a district hospital, Prachinburi. Then, I have moved to Cho Phya Abhaibhubejhr Hospital, a provicial hospital of Prachinburi, since 2001 until present. The present work position is chief of Thai Traditional Medicine department.