Providing Thai herbal recommendation based on ontology and reasoning

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Abstract. In Thailand, most of people prefer to use Thai herbs for their traditional medical treatments. However, since there are various sorts of Thai herbs, and the Thai herbal knowledge is complicated, it is difficult to find an appropriate one for each health condition. Thus, there are a number of systems and research aiming to help people to find suitable Thai herbs to cure their ailments. The authors have developed a system to provide herbal recommendations to users regarding their ailments. In the development stages, initially the Thai herbal knowledge is represented as an ontology, and then new facts are derived based on the ontology. Finally, the system provides appropriate herbal recommendations to users based on the extracted facts and the ontology. This paper describes how Thai herbal knowledge is represented as an ontology, and how the new facts are derived based on the ontology, as well as how the system provides users with herbal recommendations.

Keywords: Ontology, Reasoning, Thai herb, Herbalism, Data Visualization

1. Introduction

In Thailand, traditional herbal medicine is generally preferred when some medical treatment is needed for diseases, such as chronic ailments, dietary, longevities, etc. Since the knowledge of herbal medicine is complicated and sensitive, it is necessary to have officially certified specialists on herbal medicine. This does not mean that ordinary people are prohibited to use herbal medicine in their daily lives. Generally, not only the specialists deal with herbal medicine, but also ordinary people use herbs in their daily lives because Thai herbs are cheap and easy to find. However, because of the various sorts of herbs, it is difficult to find the appropriate herbs for each treatment of the user’s disease, chronic ailment, or other purposes. Thai people usually follow their common folk remedy for curing their ailments when they use Thai herbs, and sometimes they read books or lookup information online to learn more about the herbs. There are a lot of documents on the Web about Thai herbs in various formats. It is an effective and efficient choice for a lot of people to obtain information on the Web. However people still need to organize information by themselves, and occasionally it requires expert knowledge to organize the herbal information.

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Since the Semantic Web was proposed by Tim Berners-Lee, many Semantic Web applications have been developed. In addition, there is Semantic Web Health Care and Life Sciences Interest Group in W3C [20]. Hence, people are interested in health care systems, and Semantic Web technologies are expected to solve health care problems in life science fields. Thus, there is also some research which introduces Semantic Web technologies to provide health care information [8, 14] as well as to express certain medical knowledge [5]. The ministry of Science and Technology in Thailand also created a Thai herbal database and web site to browse the database [18]. The database has 600 kinds of Thai herbs. These systems can only search the database using simple word matching. In addition, since the Thai herbal knowledge is complicated, it is not enough to find appropriate herbs for each person. Besides, there is research which has developed systems and focused on representing Thai herbal knowledge to provide the recommendations which suit the user’s conditions [15-17]. However, there are some issues on this Thai herbal research. These systems cannot provide appropriate information if the user needs to cure multiple ailments simultaneously (e.g. fever and cough). The reason why the research cannot deal with the cure for multiple ailments is the absence of specialists in the research groups, or absence of books which have special knowledge on Thai herbal medicine in detail because the mixture of herbs requires experts’ knowledge.

In order to solve the issues of the research [15, 17] and the Thai ministry’s system [18], we have developed a system to provide herbal recommendations to users which deal with the cure for multiple ailments. In this paper, we propose to represent Thai herbal knowledge as an ontology and define inference rules to infer new facts, according to some references about traditional Thai herbal medicine [6-7]. The represented Thai herbal knowledge in ontology and inference rules enable us to deal with a cure for multiple ailments cure and to provide herbal recommendations to the users of the system.

This paper is structured as follows: The introduction provides a review of the knowledge representation of Thai herbalism to be described in section 2. In section 2, the classification of concepts of the herbalism is briefly explained and the ontology that represents Thai herbal knowledge is shown and explained as well. In addition, we describe the reasoning process, which semi-automatically constructs and completes the ontology based on the existing ontology and a set of rules that represent knowledge of Thai herbalism. In section 3, the concrete method of executing queries and deriving appropriate Thai herbs using ontology is explained. The system design and implementation is described in section 4. The system architecture and the interaction of each component, as well as the issue and its solution of expressing the recommendation data is explained in the section. The evaluation of this research is described in section 5. We focus on the comparison of this research, other existing research [15, 17-18], and general Thai herbal specialists, as well as the field test results what we have actually done in Thailand. Section 6 concludes this paper with the summary of this research and the future work that indicates the improvement based on the issue learned from the field test.

2. Representing Thai herbal knowledge

We employ an idea of ontology to represent domain knowledge that expresses the semantics of Thai herbalism. Figure 1 is a part of the knowledge representation of herbalism, which are concepts and its relations. We have employed RDF, RDF Schema and OWL to represent Thai herbal knowledge. These language formats are proposed and recommended by W3C [20]. We have used Protégé ontology editor [19] in order to edit the ontology, as well as to simulate the inference rules using JESS and SWRL within the editor.

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Our ontology has 160 herbs. The *Application* class is the description of herbs. Each herb has its application, the relation between *Herb* and *Application* class is defined as *has_application* property. The *Action* class expresses the actions which influence the human body. The ontology has 63 actions. Every Thai herb has single, or multiple actions. The *has_action* property represents that the herb has the action. The *helps* property represents the adjuvant relation between actions, which represents that some herbs can help other herbs to enhance the affection on the human body. The *Ailment* class means the ailment(s) which patients suffer. The ontology has 243 ailments. The *Action* class has *affects* property and *contraindicated* property with the *Ailment* class, hence the action affects the ailment, and the action is contraindicated to use due to the ailment.

The *Element* class represents the human body in the traditional Thai herbal system [6-7]. The human body is made up of four elements that permeate the entire universe: Earth, Water, Air, and Fire. Thai people do not believe that there is literally a speck of earth, a drop of water, or a flame of fire in each atom of the universe; each element refers not to physical substance, but to the qualities of that substance. Substances that are solid can be said to have the qualities of the Earth element. Substances that are liquid are of the Water element. Movement is the quality of the Air element. Heat is the quality of the Fire element. According to this conception, the organs of the human body can be classified into 4 categories, which are *Earth*, *Water*, *Air*, and *Fire* elements. In some Thai texts, the fifth element, *Ether*, represents the void or the absence of these four elements. The imbalance of each element causes diseases or wrong conditions in each part of the body. The 5 elements are represented as the subclasses of *Element* class.

<table>
<thead>
<tr>
<th>The elements and the parts of the human body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth(20)</td>
</tr>
<tr>
<td>Hair, body hair, nails, teeth, skin, flesh, tendons, bones, marrow, spleen, heart, liver, fascia, kidneys, lungs, large intestine, small intestine, undigested food, waste matter, brain</td>
</tr>
<tr>
<td>Water(12)</td>
</tr>
<tr>
<td>Bile, mucus, pus, blood, perspiration, body fat, tears, saliva, clear mucus, fluid in the joints, urine</td>
</tr>
<tr>
<td>Air(6)</td>
</tr>
<tr>
<td>Air which starts at the feet and rises to the head, air which starts from the head and descends to the feet, air in the abdominal cavity, air which circulates in the intestines and stomach, air which circulates throughout the body, the breath inhaled and exhaled</td>
</tr>
<tr>
<td>Fire(4)</td>
</tr>
<tr>
<td>Body heat which warms the body, body heat which makes the body feel hot and uncomfortable, heat which causes senility and causes the body to wither and dry, the heat to digest food</td>
</tr>
<tr>
<td>Ether(10)</td>
</tr>
<tr>
<td>Two eyes, two nostrils, the two ears, the mouth, anus, urethra, vagina or seminal passage.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The ten tastes and their effects on the elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Astringent</td>
</tr>
<tr>
<td>Oily(Nutty)</td>
</tr>
<tr>
<td>Salty</td>
</tr>
<tr>
<td>Sweet</td>
</tr>
<tr>
<td>Bitter</td>
</tr>
<tr>
<td>Toxic(Nauseating)</td>
</tr>
<tr>
<td>Sour</td>
</tr>
<tr>
<td>Hot(Spicy)</td>
</tr>
<tr>
<td>Bland</td>
</tr>
<tr>
<td>Aromatic(Cool)</td>
</tr>
</tbody>
</table>

The correspondence between each element and the
parts of the human body are shown in Table 1 [6-7]. According to Table 1, 20 subclasses are under *Earth* class as shown in Figure 2, 12 subclasses are under *Water* class, 6 classes are under *Air* class, 4 subclasses are under *Fire* class, 10 subclasses are under *Ether* class. The full class level definition is shown in the Appendix A. Since the human body is classified as shown in Table 1, we can assert disorder-of property between *Ailment* and *Element* class. The disorder-of property means the ailment is caused by the disorder of the elements.

The *Taste* class represents the tastes of Thai herbs. Thai Herbal medicines are traditionally classified into 10 “tastes” classes according to the primary taste of the herbs [6-7]. Since each element is associated with several organs and organ systems, and since each element is associated with several tastes, the tastes provide the link between diagnosis and herbal therapy. The classification of tastes and its influence on each element is shown in Table 2. The 10 tastes are classified as subclasses of *Taste* class. The relation between *Taste* and *Element* class are represented as increases and decreases properties.

Before the explanation about inference rules, we describe the basic diagnosis method for the derivation of appropriate herbs for each ailment. Diagnosing disease according to the five elements is thus a crucial part of Thai herbalism. Diagnostic skills take many years to develop, and traditionally, the apprentices in Thai herbalism need to study under able teachers for decades before they are considered to be healers in their own right. Therefore, we do not act as the Thai herbal specialist in this research, but we utilize the knowledge which is explained by the herbal specialist [6-7].

Referring back to the element and the taste description, the excess Fire patient could be given astringent, sweet, bitter, bland, and aromatic tastes of herbs and foods to calm the Fire element, and should stay away from oily, salty, toxic, sour, and hot tastes’ herbs and foods in order not to increase the Fire element. This is a simple example which is caused by a disorder of only one element. In many cases, patients experience multiple ailments which point to multiple imbalances of the four elements. In these cases, more complex herbal preparations are required. Here, we explain the example of the complex herbal preparation using Table 3. Table 3 is a list of the taste of herbs to take, and herbs to avoid, in case of depleted water and excessive fire.

For example, a patient with depleted Water and excessive Fire should be given herbs which do not interfere with each other for both conditions. Referring back to the 10 taste classifications shown in Table 2, the following herbs can be used for these two conditions; referring to Table 3, we can find some herbs, which have oily and salty tastes and can help one condition of elements, but aggravate another one simultaneously. Other herbs which have toxic and hot tastes should be avoided for both conditions. The herbs that should be prescribed in this case would be sweet, bland, and aromatic herbs, which are found as herbs to take for both conditions. A blend of these three tastes could work well for this patient.

### Table 3: List of herbs to take and herbs to avoid

<table>
<thead>
<tr>
<th>Condition</th>
<th>Herbs to take</th>
<th>Herbs to avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>For depleted water</td>
<td>Oily, Salty, Sweet, Sour, Bland, Aromatic</td>
<td>Astringent, Bitter, Toxic, Hot</td>
</tr>
<tr>
<td>For excessive fire</td>
<td>Astringent, Sweet, Bitter, Bland, Aromatic</td>
<td>Oily, Salty, Toxic, Sour, Hot</td>
</tr>
</tbody>
</table>

Regarding the basic diagnosis method, we have defined the derivation process as follows:

**The derivation process**

1. Derive each herb’s affection and contraindications to the ailments, according to the relation between *Action* and *Ailment* class.

2. Derive how each ailment is caused, which means what disorder of elements causes the each ailment.

3. Derive whether each herb affects to the ailments efficaciously, or not, according to the results from the derivation process 2.

For example, in the derivation process 3, if an ailment is caused by the depletion of a particular element, and a herb affects to the ailment with increasing the depleted element, the effect of the herb is good for the ailment.

We have defined eleven rules to represent the derivation process described above. The derivation process 1 corresponds to Rule-01 and Rule-02, the process 2 corresponds to Rule-03 and Rule-04, and the process 3 corresponds to Rule-05, Rule-06, Rule-07, and Rule-08, Rule-09, Rule-10, and Rule-11, are the rules to resolve the discrepancies which might be derived by the derivation processes. The results of the derivations are asserted into the ontology.

An inference rule consists of 2 parts. The left side
of an arrow is antecedent, and the right side is consequent. The characters which start with “?” are variables and they are all instances asserted under classes. If the antecedent is satisfied, the rule gets fired, then the specified property gets asserted between specified instances.

**Rule-01**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ has_action(?h, ?a) ∧ affects(?a, ?al)
→ affects(?h, ?al)

**Rule-02**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ has_action(?h, ?a) ∧ contraindicated(?a, ?al)
→ contraindicated(?h, ?al)

**Rule-01** means “If a herb ?h has an action ?a and the action ?a affects an ailment ?al, then the herb ?h affects the ailment ?al.” In this case, a herb ?h has an action ?a, and the action ?a affects an ailment ?al, then the property affects gets asserted between Herb class’s instance ?h and Ailment class’s instance ?al.

The derivation process 1 is done by **Rule-01** and **Rule-02**, the meaning of **Rule-01** is explained above, and the **Rule-02** is almost the same as **Rule-01** except the affects property is changed to contraindicated property.

**Rule-03**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ decreases(?t, ?e) ∧ has_taste(?h, ?t)
⇒ depletion_of(?al, ?e)

**Rule-04**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ decreases(?t, ?e) ∧ has_taste(?h, ?t)
⇒ excess_of(?al, ?e)

**Rule-03** and **Rule-04** are rules to derive depletion of and excess of properties. The depletion of property means that the ailment is caused by the depletion of a particular element. The excess of property is the opposite property from depletion of property.

In order to consider what herbs are appropriate for patients, we need to know how the ailment is caused, that means which element is depleted, or excess. Therefore, **Rule-03** means “If an ailment ?al is caused by the disorder of an element ?e, and a herb ?h affects the ailment ?al, and the herb ?h has a taste ?t, and the taste ?t increases ?e, then the ailment ?al is caused by the depletion of the element ?e.” **Rule-04** is similar to **Rule-03**. **Rule-04** means “if an ailment ?al is caused by the disorder of an element ?e, a herb ?h affects the ailment ?al, and the herb ?h has a taste ?t, and the taste ?t decreases ?e, then the ailment ?al is caused by the excess of the element ?e.”

**Rule-05**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ depletion_of(?al, ?e) ∧ has_taste(?h, ?t)
⇒ good_for(?h, ?al)

**Rule-06**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ excess_of(?al, ?e) ∧ has_taste(?h, ?t)
⇒ good_for(?h, ?al)

**Rule-07**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ depletion_of(?al, ?e) ∧ has_taste(?h, ?t)
⇒ bad_for(?h, ?al)

**Rule-08**
Herb(?h) ∧ Action(?a) ∧ Ailment(?al)
∧ Element(?e) ∧ Taste(?t) ∧ affects(?h, ?al)
∧ excess_of(?al, ?e) ∧ has_taste(?h, ?t)
⇒ bad_for(?h, ?al)

From **Rule-05** to **Rule-08** are rules to derive whether the herb is good, or bad for the cure of the ailment, which are the crucial relationships in order to provide herbal recommendation to users using the ontology. **Rule-05** means “If a herb ?h affects an ailment ?al, and the ailment ?al is caused by the depletion of an element ?e, and the herb ?h has a taste ?t, and the taste ?t increases an element ?e, then the herb ?h is good for the cure of the ailment ?al.”
Rule-05 finally gets good_for property asserted. Rule-06 is almost the same as Rule-05, except for the property between the taste ?t and the element ?e. Rule-07 is the opposite rule of Rule-06, which derives bad_for property. Rule-08 is similar to Rule-07.

Rule-09
Herb(?h) ∧ Ailment(?al) ∧ good_for(?h, ?al) ∧ contraindicated(?h, ?al) → bad_for(?h, ?al)

Rule-10
Herb(?h) ∧ Ailment(?al) ∧ bad_for(?h, ?al) ∧ good_for(?h, ?al) → bad_for(?h, ?al)

Rule-11
Herb(?h) ∧ Ailment(?al) ∧ affects(?h, ?al) → good_for(?h, ?al)

From Rule-09 to Rule-11 are the rules to resolve the discrepancies. In Rule-09, a herb ?h is good for an ailment ?al but the herb ?h is contraindicated due to the ailment ?al, Rule-09 asserts bad_for property between ?h and ?al. Rule-10 is also for resolving discrepancy, which means if a herb ?h is good for an ailment ?al, but concurrently the herb ?h is bad for the ailment ?al, then Rule-10 asserts bad_for property between ?h and ?al instances. Obviously, Rule-09 and Rule-10 are not fired usually, because the meanings of the rules themselves have discrepancies. These two rules are set for resolving the discrepancies which are derived when there are some discrepancies in the ontology. Thus, if the ontology contains some errors, these rules might work for resolving the discrepancies.

Rule-11 is a rule to derive good_for property with regarding only affects property. This rule gets fired when the ontology has errors. Sometimes, we cannot assert the disorder_of property because the information about the ailment is not enough. Therefore, there are some ailments which do not have disorder_of property. In this case, the good_for property will not get asserted, even if a particular herb is good_for some ailments. In order to deal with these cases, Rule-11 gets good_for property asserted. This rule does not make any confusion in the derivation, because Rule-09 and Rule-10 fix the discrepancies.

After the execution of all the inference rules, which are from Rule-01 to Rule-11, the ontology has all facts to provide users with herbal recommendation. This derivation process is the semi-automatic ontology construction which completes the ontology to get ready for providing herbal recommendation to users. The complete list of the inference rules is Appendix B.

In our system, if a patient has an ailment, the patient can view the completed ontology. The keys of view are good_for and bad_for property. By getting all the properties of good_for and bad_for property, the patient gets to know which herbs to take and herbs to avoid. Subtracting bad herbs from the set of good herbs, then the result is the herbs to take. Even if the user has multiple ailments, he/she does almost the same procedure as the single ailment case. View the completed ontology, and get all good_for and bad_for property for the multiple ailments, and subtract bad herbs from the set of good herbs, then the result becomes the herbs to take.

3. Deriving appropriate herbs

As explained in the previous section, the system views the completed ontology in order to provide users with proper herbal recommendation. The query language which we use is SPARQL. Here, we explain the viewing process using examples of queries to view the good_for property and bad_for property from the ontology.

Query-01
SELECT ?subject ?object
WHERE {
?subject <ThaiHerbalOntology.owl#good_for> ?object
}

Query-02
SELECT ?subject ?object
WHERE {
?subject <ThaiHerbalOntology.owl#bad_for> ?object
}

Since SPARQL is an RDF query language, it enables us to view the ontology. Query-01 and Query-02 are consisting of 2 parts, which are the SELECT statement and WHERE statement. Both statements have words which begin with “?”. The words which begin with “?” represent the subject and
object of RDF triple. Therefore, the meaning of Query-01 is “select the subject and object of RDF statement where the property is good_for property”. In our system, finally we view the completed ontology to get all good_for and bad_for property to show herbal recommendation to users. The Query-01 and Query-02 are the queries to get all good_for and bad_for property from the ontology.

4. System implementation

In this section, the architecture of the system and its functionalities are explained by using Figure 3.

The derivation of properties explained in section 2 is a preprocess in the system before providing recommendation to users. The inference engine infers the facts based on the Thai herbal ontology and rules. The inferred facts are the relations between herbs and ailments, that mean which herb is good or bad for particular ailments. The visualization is important for providing herbal recommendations to users to help comprehending the recommendations. Users can access the system using a Web browser. Firstly, a user selects his/her ailment(s), and submits it to the system. Then client side sends the submitted data to server side. In the server side, a view engine receives the submitted user’s ailment(s), and then views the Thai herbal ontology using SPARQL query language. View engine gets a viewed ontology containing the herbal data related with user’s ailment(s). The herbal data in the viewed ontology are recommendations to the user which is later visualized by the interface. After the viewing, view engine passes the viewed ontology to explanation engine. Explanation engine receives the viewed ontology, and then executes query to get static data about the recommended herbs from the database, which are pictures, and usages of herbs. These static data are used when the system shows the recommended herbal information to users. Explanation engine sends the list of recommended herbal information described in the viewed ontology, and related static data to client side. Then in the client side, the interface receives the data from explanation engine. Finally, the interface shows the herbal recommendations. Inference engine works when ontology has been modified. It derives all the facts to provide to users before the users use the system.

As explained above, the system retrieves data such as good_for and bad_for relations from the ontology as the herbal recommendation to users by viewing the ontology after the derivation process. However, an issue remains in expressing the retrieved data on the interface. Ordinary ways of expressing data are using table, itemization, text etc. Considering the structure of the recommendation data, these ordinary ways of expressing data are not sufficient enough to show the information clearly and intuitively.

Considering a scenario that there are 2 ailments (ailment 1 and ailment 2) which a patient wants to cure using Thai herbs. The system provides recommendations for each ailment he/she has regarding the combination of herbs. Thus, the recommendation can be expressed in tables by listing the recommendation as shown in Figure 4.
Looking at just one of the tables, there is no problem understanding the content in the table. However, the patient wants to cure 2 ailments and he/she picks up the herb(s) which is/are good for both ailments. The case in Figure 4, Herb A is good for both ailments. Herb E is good for only ailment 2, and does not affect ailment 1. Herb B is good for ailment 1, but bad for ailment 2 so that it should be avoided by the user. Herb D is bad for ailment 1, and does not affect ailment 2, however the user needs to keep Herb D in mind to read the table of ailment 2 in order to avoid it when it appears as good herb.

As the scenario suggests, the patient needs to match the herbs listed in each table, and infer which herb is the appropriate one or which one should be avoided. This is the issue that remains in expressing data on the interface.

For the solution of the issue mentioned above, we propose to visualize the recommendation data. We employ to use CG animation to express the recommendation data. There are some researches which are solving problems in expressing data by using data visualization method [2, 9]. It is well established that visualization is efficient to express structural, relational data. In our research, the idea for the visualization is to put boxes with the herbal pictures on them in 3D space. Also, the herbs which a user should take together are placed near to each other, and the herbs which the user should avoid to take together are placed far from each other.

The screenshot of the visualized data is shown in Figure 5. In the screenshot, there are 2 ailments written in the 3D space, and each ailment is connected to some boxes. These directly connected herb boxes are the recommendation for each ailment. The characteristic of this visualization method is the line drawn in between 2 boxes shown in Figure 6. The connected boxes mean that, by taking these two herbs the patient can cure both ailments that are connected to each box.

By using this visualization method, the issue on expressing recommendation is solved. Users can recognize the herbal recommendation intuitively by looking at the results in the CG space.

We have implemented the client side using Processing programming language [3-4]. Processing is an open source programming language and environment for people who want to program images, animation, and interactions. In the implementation of server side, we have used Java programming language. Inference engine and view engine are implemented using Pellet [12]. Pellet is a Java based framework for building Semantic Web applications. It provides a programmatic environment for RDF, RDFS and OWL, SPARQL and includes a rule-based inference engine.

5. Evaluation

Since this research is focusing on helping Thai people to find appropriate herbs, it is important and effective to perform an evaluation by comparing our system with the existing researches [15, 17-18] and general Thai herbal specialists in the aspect of helping people. Diagnosis and complicated mixture are prohibited for non-human to do in Thailand, thus, this research is not aiming at developing an expert system that works as a herbal specialist. We are fo-
cusing on providing people with appropriate herbal recommendation based on user’s input. In addition to the comparison, it is necessary to perform a field test and get a feedback from users to consider the validity of the system. We have demonstrated our system in Uttaradit providence, Thailand and got a valuable feedback for the evaluation of our system.

The comparison and the result from the field test are described in the rest of this section.

5.1. Evaluation by comparison

Table 4 represents the evaluation and the comparison. As described in section 1, our system is focusing on people who hardly afford to go to see doctors because of the geographical and/or financial difficulties, thus, there are rows of ‘mobility’ and ‘cost’ in table 4. Furthermore, ‘quality of information’ is also in the table because the question about the aspect is obviously one of the most essential part of the evaluation.

Since the Internet is widely available in Thailand, our system is usable in most of the places if using a PC. Also people can use our system from a browser on a mobile phone. People who cannot afford to use the Internet can use computers at local sanitarium, dispensary etc. Besides, Thai herbal specialists are not ubiquitous in several places in Thailand. Therefore, comparison of ‘mobility’ can be given as shown in the table. The evaluation is classified into 3 levels, which are excellent, good, and fair. Since our system and existing systems are all web application and accessible via the Internet, the mobility is characterized as excellent. In contrast, Thai herbal specialist is characterized as fair. Also the financial cost of Thai herbal specialist is more expensive than using our system or existing systems because the specialists usually perform a diagnosis and have herbal mixtures for the patients. Considering some serious diseases, herbal specialist are obviously appropriate to go to see in order to get proper medications. However, Thai people tend to use Thai herbs to cure nonserious diseases, the diagnosis process is sometimes not necessary. Comparing to the cost of visiting Thai herbal specialists, our system and the existing systems are characterized as excellent in cost. In the quality of information, as mentioned above, Thai herbal specialist has advantage because they perform a diagnosis and complicated herbal mixtures. Therefore Thai herbal specialist’s quality of information is excellent. In contrast, existing systems do not consider the combination of herbs, thus they are characterized as fair in the aspect of the quality of information. Beside, since our system considers the combination of herbs, the quality of information is characterized as good.

<table>
<thead>
<tr>
<th></th>
<th>Thai herbal specialist</th>
<th>Proposed system</th>
<th>Existing systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>fair</td>
<td>Excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Cost</td>
<td>fair</td>
<td>Excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Quality of information</td>
<td>excellent</td>
<td>Good</td>
<td>fair</td>
</tr>
</tbody>
</table>

5.2. Evaluation by field test

We have performed a field test at 2 sanitariums and a public health office in Uttaradit province, Thailand. The province is approximately 490 kilometers far from Bangkok, the capital of Thailand. We have received 170 questionnaires answered by the users and staffs of the sanitarium, and some advices from the public health officer of Uttaradit province. Table 5, 6, 7, 8 and 9 are the results of the questionnaires.

Table 5: Trust in Thai herbs

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>Not sure</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think Thai herbs can treat ailments?</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 6: How often Thai people use Thai herbs

<table>
<thead>
<tr>
<th></th>
<th>Constantly</th>
<th>Frequently</th>
<th>Sometimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often do you use Thai herbs to cure your ailments?</td>
<td>11.8%</td>
<td>82.3%</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

In Table 5, questionee’s trust in Thai herbs is examined. All of questionee answered that they think Thai herb can treat ailments. Also in Table 6, 94.1% of questionee answered that they use Thai herbs constantly or frequently in order to cure their ailments. In Table 7, none of questionees answered that there is no Thai herbs around their house area. Questionees answered that normal amount of Thai herbs are findable in their house area. Although the answers in
Table 6 and 7 are not qualitatively precise, it is clear that questionees use Thai herbs frequently and Thai herb is obtainable in their house area.

Table 7: Question about background

<table>
<thead>
<tr>
<th>How much Thai herbs are there in your house area?</th>
<th>A lot</th>
<th>Normal</th>
<th>Few</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.7%</td>
<td>58.8%</td>
<td>23.5%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 8 examines that where questionees get Thai herbal information. The question in Table 8, questionees can select multiple choices if applicable. As Thai herbs are basically folk remedies, Hearsay is the most common way to get Thai herbal information. The following choices are book, TV, and the Internet. Although the field test area is not as civilized as Bangkok, the capital of the country, the Internet is a possible choice for approximately 30% of the questionees.

Table 8: Where to get Thai herbal information

<table>
<thead>
<tr>
<th>Where do you get Thai herbal information?</th>
<th>Hearsay</th>
<th>Book</th>
<th>TV</th>
<th>Internet</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>140</td>
<td>80</td>
<td>60</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>82.3%</td>
<td>47.0%</td>
<td>35.2%</td>
<td>29.4%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

Table 9 examines the performance of our system. We have not discussed the effectiveness of the treatment of herb itself, but the usefulness and the satisfaction of questionee’s in our system. The usefulness of our system is evaluated as good by most of the questionees. However, some of questionees are not familiar with using a PC, thus, it is difficult for them to use mouse and keyboard to input necessary information. This is why 5.9% of them answered that the interface ‘should be improved.’ Since this field test was performed before the implementation of the interface which has visual input function and visualizes the recommendation data, the interface was unclear for the questionees who are unfamiliar with using a PC. Since the visual interface is implemented now, this issue is already solved. Despite of the unfamiliarity among some questionees, the satisfaction of our system is characterized as excellent or good by all of the questionees.

Table 9: Question of the system

<table>
<thead>
<tr>
<th>How much is the system useful for you?</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Should be improved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29.4%</td>
<td>64.7%</td>
<td>0%</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How much is your satisfaction in the system?</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Should be improved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>64.7%</td>
<td>35.3%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 9: Question of the system

We have also got some valuable idea for further development of functions in our system. The demand from several questionees is to implement a function to monitor user’s health condition. It is basically a SMS or e-mail sent to the users from our system if the vital data records seem to be unusual. Therefore we have developed a system to collect vital data automatically from users via Bluetooth communication.

6. Conclusion

We have developed the Thai herbal recommendation system to solve the issues of Thai ministry’s system [18] and some related research [15, 17]. We have proposed to represent the Thai herbal knowledge as ontology, define inference rules based on the principles explained by a specialist [6-7], and infer new facts using them. The proposals enabled us to deal with multiple ailments cure, and to provide herbal recommendations for the cure of multiple ailments. Moreover, in order to help people to understand the system’s output, we have proposed a visualization method as described in section 4. Since we use ontology and some Semantic Web technology, knowledge representation and extraction became possible even though the Thai herbal knowledge was sophisticated. If we did not use these technologies, the system construction must be more difficult and complicated. Furthermore, from the view points of interoperability, reusability and scalability, using the ontology and the inference mechanism has an advantage because we can easily add new herbal information into the ontology, or change rules to derive new facts from the ontology.
We have developed a vital data collection system to utilize for users to monitor users’ health conditions. As the future work, we are currently working on embedding the vital data collection system in the Thai herbal recommendation system as shown in Figure 7. The use case scenario is going to be as follows: Users can measure their weight and blood pressure using sensors, and send it to the vital data monitoring system to store. Also the vital data monitoring system provides users with the interface to check their vital data.

This new feature is an improvement for the feedback from the field test explained in section 5, which helps users to keep their health more efficiently.

The concrete rules of utilizing the collected vital data are still under the discussion, and are soon defined and implemented in the system.

References

Appendix A: Full class level definition of Thai herbal Ontology
### Appendix B: List of inference rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rule 1</strong></td>
<td>If a herb $h$ has an action $a$ and the action $a$ affects an ailment $al$, then the herb $h$ affects the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 2</strong></td>
<td>If a herb $h$ has an action $a$ and the action $a$ affects an ailment $al$, then the herb $h$ affects the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 3</strong></td>
<td>If an ailment $al$ is caused by the disorder of an element $e$, and a herb $h$ affects the ailment $al$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the ailment $al$ is caused by the depletion of the element $e$.</td>
</tr>
<tr>
<td><strong>Rule 4</strong></td>
<td>If an ailment $al$ is caused by the disorder of an element $e$, and a herb $h$ affects the ailment $al$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the ailment $al$ is caused by the excess of the element $e$.</td>
</tr>
<tr>
<td><strong>Rule 5</strong></td>
<td>If a herb $h$ affects an ailment $al$, and the ailment $al$ is caused by the depletion of an element $e$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the herb $h$ is good for the cure of the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 6</strong></td>
<td>If a herb $h$ affects an ailment $al$, and the ailment $al$ is caused by the excess of an element $e$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the herb $h$ is good for the cure of the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 7</strong></td>
<td>If a herb $h$ affects an ailment $al$, and the ailment $al$ is caused by the depletion of an element $e$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the herb $h$ is bad for the cure of the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 8</strong></td>
<td>If a herb $h$ affects an ailment $al$, and the ailment $al$ is caused by the excess of an element $e$, and the herb $h$ has a taste $t$, and the taste $t$ decreases the element $e$, then the herb $h$ is bad for the cure of the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 9</strong></td>
<td>If a herb $h$ is good for an ailment $al$, and the herb $h$ is contraindicated due to the ailment $al$, then the herb $h$ is bad for the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 10</strong></td>
<td>If a herb $h$ is bad for an ailment $al$, and the herb $h$ is good for the ailment $al$, then the herb $h$ is bad for the ailment $al$.</td>
</tr>
<tr>
<td><strong>Rule 11</strong></td>
<td>If a herb $h$ affects an ailment $al$, then the herb $h$ is good for the ailment $al$.</td>
</tr>
</tbody>
</table>