Abstract—In Southeast Asia, durian is affectionately called the king of fruit. Durian is the most popular crop planted in eastern and southern of Thailand. The total crop is around 600,000 tons per year; among this, 500,000 tons of the total production were exported worldwide. In Thailand, the knowledge of durian production is based on experience from generation to generation, especially the knowledge of durian pests and diseases control. This paper presents the ontology knowledge based for durian pests and diseases retrieval system. The major contributions of the system consist of 1) the stored knowledge of durian pests and diseases and 2) the diagnosis of durian diseases and the suggestions for the treatments. The ontology knowledge consists of 8 main classes: 1) diseases, 2) pests, 3) cultivars, 4) symptoms of bunch, 5) leaf area symptoms, 6) symptoms of the branches and trunk, 7) symptoms of fruit, and 8) symptoms of root and growth. The experimental results yielded 100% of precision, 88.33% of recall, and 93.8% of overall performance.

Index Terms—Ontology, semantic web, durian cultivars, durian pests, durian diseases, information retrieval.

I. INTRODUCTION

Thailand has a favorable weather condition and productive land for the cultivation of tropical fruits. The fruits productions of Thailand have been considered as the premium fruits and there are high demands in the international markets. It can generate high export incomes which accounts for US$360.89 million in 2016 [1]. In Southeast Asia, Thailand is the main supplier and exporter of tropical fruits such as durian, guavas, mangoes, mangosteens, bananas, oranges, rambutans, coconuts, and lychee. In 2017, durian production accounted for 600,000 tons and the export values accounted for over US$ 301.75 million [1]. In Thailand, there are 234 varieties registered with the government of which about 60-80 varieties are commercially cultivated [2]. Generally, Thai durian cultivars can be divided into 3 groups according to maturity indices:

1) Early maturity (103-105 days); there are 3 cultivars in this group: Chanee, Gradum-tong and Lueng.
2) Medium maturity (127-130 days); there are 3 cultivars in this group: Monthong, Gob, and Kan Yau.
3) Late maturity (140-150 days); there are 3 cultivars in this group: Gumpan, Enak, and Tong-yoi-chat.

According to the 3 groups of maturity indices, the 3 most popular cultivars are Monthong, Chanee and Kanyao (see Fig. 1). Durian is the most popular crop planted in eastern and southern of Thailand, of all the cultivated durian areas in Thailand; Monthong comprises 41%, Chanee 33%, Kan Yau 5%, Gradum-tong 2%, and the rest are minor varieties [2].

Although the increasing popularity of durian in world market that caused the price had risen up to 20 times over in four years [3], there is no repository to keep the technical aspects of durian production in the right place. The knowledge of durian production is still based on experience from generation to generation, especially the knowledge of durian pests and diseases control [4], [5]. This paper presents the ontology knowledge based for durian pests and diseases retrieval system. The ontology knowledge consists of 8 main classes: 1) diseases, 2) pests, 3) cultivars, 4) symptoms of bunch, 5) leaf area symptoms, 6) symptoms of the branches and trunk, 7) symptoms of fruit, and 8) symptoms of root and growth. This paper is organized as follows. Section II describes the experimental framework used in this paper (the knowledge acquisition, the ontology base development, and the sematic search system). Section III describes the results. Finally, Section IV presents the conclusions and future works.

II. SYSTEM FRAMEWORK

The major contributions of the system consist of 1) the stored knowledge of durian pests and diseases and 2) the diagnosis of durian diseases and the suggestions for the treatments. Fig. 2 shows the system framework.

The system framework consists of 3 main parts:

A. The Knowledge Acquisition

In this step, we collected the knowledge of durian production, durian pests and diseases control from the experienced farmers in eastern and southern of Thailand by using the in-depth interview [6]. We also collected the research reports, books, and articles from the Agricultural Research Development Agency in Thailand [7]. We provide the major diseases and pests of durian in the appendix.
B. The Ontology Base Development Cycle

After gathering the knowledge and checking the correctness in the first step, we developed the knowledge ontology by adopting from the two frameworks presented in [8] and [9] (we surveyed many literatures about creating and processing knowledge ontology, and we found that these 2 frameworks were appropriated for the ontology in the agricultural knowledge. The ontology base development consists of 6 consecutive steps:

1) Define Determining the domain and scope of the ontology-based system; as we mentioned earlier; the system has been designed and developed for the diagnosis of durian diseases and pests, therefore the system can give the suggestions for the treatments. By the collecting the tacit knowledge of the durian farmers from generation to generation, and the best practices of durian production from the Agricultural Research Development Agency in Thailand, the system also gives the suggestions of durian production plan based on the soil conditions, weathers, and rainfall in each year.

2) Identifying classes and relations; the ontology knowledge consists of 8 main classes: 1) diseases, 2) pests, 3) cultivars, 4) symptoms of bunch, 5) leaf area symptoms, 6) symptoms of branches and trunk, 7) symptoms of fruit, and 8) symptoms of root and growth.

3) Defining the concept; we defined the properties into 3 types (IS-A, p/o, and a/o; we demonstrated the hierarchy clustering using the Dendrogram as shown in Fig. 3):
   a) “IS-A” e.g., Powdery mildew is-a durian disease.
   b) “part-of” e.g., Anthracnose symptoms on the durian bunch part-of (p/o) durian disease.
   c) “attribute-of” e.g., Disease cause attribute-of (a/o) durian disease.

4) Defining the constraints, e.g., classes Growth has 2 constraints: grow slowly and die.

5) Creating an instance, e.g., the spots on the leaf is the instance of the Leaf spot disease.

6) Rechecking the concept by consulting the experts.

As mentioned earlier, to construct the knowledge, the knowledge acquisition and modeling based on knowledge...
engineering approach required an effective tool for capturing expert opinion in form of durian pests and diseases control practice guidelines. We investigated many tools to use as the ontology editor, and we found that Protégé [10] and Hozo [11] are now the well-known ontology editors. Fig. 4 shows the example of the Hozo ontology editor used in the ontology-based clinical reminder system for diabetes patient registry [12]. Based on the Hozo ontology editor, we built the model of structural knowledge from the durian farmers and the white papers or the best practices from the Agricultural Research Development Agency in Thailand.

The Ontology-based Semantic Retrieval for Durian Pests and Diseases Control System consists of 8 classes as shown in Table I. In which, durian disease is the class that could be related to all classes in the ontology.

| Attribute              | Relation | Class                        |
|------------------------|----------|------------------------------|
| Disease_ID             | a/o      | Durian pests and diseases    |
| Disease_Name           | a/o      |                              |
| Disease_Symptom        | a/o      |                              |
| Disease_Cause          | a/o      |                              |
| Disease_Outbreak       | a/o      |                              |
| Disease_Prevention     | a/o      |                              |
| Disease_Contagion      | a/o      |                              |
| Pest_Disease           | p/o      | Pests                        |
| Durian_Cultivar        | p/o      | Cultivars                    |
| Symptom_Bunch          | p/o      | Symptoms of bunch            |
| Symptom_leaf           | p/o      | Leaf area symptoms           |
| Symptom_Branch         | p/o      | Symptoms of branches and trunk |
| Symptom_fruit          | p/o      | Symptoms of fruit            |
| Symptom_Root_Growth    | p/o      | Symptoms of root and growth  |

C. The Semantic Search System

After rechecking the concept with the durian experts and checking the references in arda.or.th, the last phase of the framework is to develop the semantic search system. We used the Ontology Application Management Framework: OAM [13]. The OAM consists of 2 major components:

1) The Database to Ontology Mapping Component; we used OWL (Web Ontology Language) for mapping data from database to the ontology base. The results of mapping data will be transformed into RDF (Resource Description Framework) format.

2) The Search Configuration Component; this User Interface (UI) will be used as the query component and showing the query results. In the web-based GUI, the user can choose the pest and disease symptoms; with the configuration setting and the relations of the durian symptoms, the query results will be shown on the screen.

III. RESULTS

Fig. 5 shows the screen captured of Ontology-based Semantic Retrieval for Durian Pests and Diseases Control System.

Fig. 6 shows the search screen of the system, e.g. the user may search by the symptoms of bunch and the result of the search will be shown at the bottom of the screen.

As shown in Fig. 6, by given the query of condition (Pest_Disease) Is A (Fruit boring caterpillar), the results are shown below:

Disease_ID = 02;
Disease_Cause = Fruit boring caterpillar;
Disease_Prevention = Check durian usually, prevent the worm by wrapping the durian fruit with a plastic cover (Perforated ventilation) [7];
Disease_Symptom = Fruit boring caterpillar will destroy the durian fruit, normally found during 2-3 months after pollination and durian will be rotten and fall before its maturity. By the observation, the durian farmer may see the hole on the durian fruit and obviously see the water comes

| Case | Query                                                                 | | | | | |
|------|-----------------------------------------------------------------------|---|---|---|---|---|
| 1    | Symptoms of bunch: White mold                                         | 1 | 1 | 2 | 100 | 50 |
| 2    | Leaf area symptoms: Burnt leaf                                        | 1 | 1 | 1 | 100 | 100 |
| 3    | Leaf area symptoms: Pink mold Symptoms of branches and trunk: Pink mold| 1 | 1 | 1 | 100 | 100 |
| 4    | Symptoms of branches and trunk: Shot hole borer                       | 2 | 2 | 3 | 100 | 66.67 |
| 5    | Symptoms of fruit: die Symptoms of root and growth: die               | 4 | 4 | 4 | 100 | 100 |
| 6    | Symptoms of fruit: grow slowly                                       | 2 | 2 | 3 | 100 | 66.67 |
| 7    | Symptoms of root and growth: Root rot and Foot rot                    | 1 | 1 | 1 | 100 | 100 |
| 8    | Pest: Long horned beetle                                             | 1 | 1 | 1 | 100 | 100 |
| 9    | Symptoms of bunch: die Pest: Mealy bugs                              | 3 | 3 | 3 | 100 | 100 |
| 10   | Pest: Durian psyllid                                                 | 2 | 2 | 2 | 100 | 100 |
|      | Average                                                               | 100 | 88.33 |
out [7];
We evaluated our system in terms of the precision, recall, and overall performance. Equation 1, 2, and 3 are shown below:

Precision: \[ P = \frac{|A|}{|B|} \]  
Recall: \[ R = \frac{|A|}{|C|} \]

Overall performance:

\[ F = \frac{2(RP)}{(R+P)} \]

where, \(|A|\) = Number of the correct answer
\(|B|\) = Number of total answers
\(|C|\) = Number of total answers by the experts

The system was tested by 2 experts using 10 cases of the query. The correctness of the query results must be given by 2 experts, otherwise that case would be marked “fail”. Table II shows the experimental results.

IV. CONCLUSIONS AND FUTURE WORKS

By given 10 cases of the query, the experimental results yielded 100% of precision, 88.33% of recall, and 93.8% of F-measure. The system provides 8 classes of pests and diseases of 3 durian cultivars (Monthong, Chanee and Kanyao). We noticed that there were some errors in the case of the Burnt leaf and the Leaf spot diseases (the symptoms of these diseases have the same physical characteristics; therefore, only an experienced durian farmer can notice the different of the spots on the leaves).

The recommendations for the future such as 1) adding more pests and diseases, 2) providing the real-time update the knowledge repositories and the feature which is capable of retrieving the new knowledge for durian pests and diseases control.

APPENDIX

In Thailand, we can classified the major pests of durian into 6 types: 1) Durian seed borer, 2) Durian psyllids, 3) Fruit boring caterpillar, 4) Mealy bugs, 5) Shot hole borer, and 6) White grub [14]. Table III shows the 6 major pests of durian.

TABLE III: THE 6 MAJOR PESTS OF DURIAN IN THAILAND

| Pest name | Pest outbreak |
|-----------|---------------|
| Durian seed borer (Mudaria luteoleprosa Hollaway) | Fruit and seed |
| Durian psyllids (Planococcus minor) | Leaf, flower, and fruit |
| (Allocarida Maleysensis) | Trunk and branch |
| Fruit boring caterpillar (Conogethes punctiferails) | Root |
| Mealy bugs (Planoceocceus minor) | Long horned beetle (Anomala sp.) |
| Shot hole borer (Xyleborus fornicatus) | |

The mature durian seed borer lays eggs on the fruit near the calyx. When the fruit is 6-week old until the harvest period, it pierces through to eat the seed and excretes to dirty the flesh. The worm lives in the fruit until the fruit is mature. When the worm is mature, it will pierce through the peel to stay in the silk case underground. Most of the destroyed durian fruit are in the phase that the seed is robust [15]. In controlling seed borer, phosalone + cypermethrin is the most effective insecticide followed by endosulfan and carbaryl [16].

The Pink Disease normally caused by bassiomyces fungus also known as Corticum salmonicolor. The disease attacks the twigs and smaller branches of durian trees causing wilting and dieback. Four years and above old durian tree are subject to this attack due to bushy canopies. Those areas with heavy rainfall especially on inland area are recorded high incidence of this disease. The silky white mycelia threads appear on the bark of small branches or twigs. This mycelia threads later change appearance to pink color as the bark dies. The infected wood turns dark brown and their leaves yellow foliage in which it drops. The branches die and finally the disease results wilting and death of foliage on the infected twig or...
Normally, the diseases of durian can be found in the other fruits, e.g. the major diseases of durian are Fruit rot, Pink mold, White mold, and Burnt leaf [23] (See Table IV).

**CONFLICT OF INTEREST**

The author declares no conflict of interest.

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