eco.mont – Volume 16, Number 1, January 2024
ISSN 2073-106X print version – ISSN 2073-1558 online version: http://epub.oeaw.ac.at/eco.mont
https://dx.doi.org/10.1553/eco.mont-16-1s39

Exploitation of an ontology in a semantic web: A case study transferring Thai lichen data into domain ontologies

Pemika Khamweera, Natthawut Chaloyard, Anawat Klaysood, Somkid Soottitantawat, Wetchasart Polyiam, Supattara Phokaeoc, Nikorn Sutthisangiam & Porawat Visutsak

Keywords: lichens, diversity, ontology, semantic web, knowledge-based system

Abstract

More than 100 lichens have been found and identified in Thailand over the last century. Lichens perform useful environmental functions. Normally, they grow on trees, rocks and soils, in various forms and colours. They provide shelter and food for animals and plants. Lichens can also be used as indicators of air pollution, and some are researched for drugs, dyes, deodorants and extracts. This paper presents an ontology for lichens in Thailand, using lichen data from Khao Pluang, in Lopburi, Thailand. The database developed makes major contributions in the amount of knowledge on lichens that it stores, including the latitude and longitude of lichens at Khao Pluang specifically, and images of lichens. The system was implemented via web and mobile applications. The ontology knowledge consists of 6 main classes: 1) scientific name, 2) lichen type, 3) date found, 4) uses of the lichen, 5) function as an air pollution indicator, and 6) specific features of the individual lichen. Evaluation of the system was carried out by lichen and ontology specialists using the Software Usability Measurement Inventory (SUMI).

Profile

Protected area

Genetic Conservation Project Under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn

Country

Thailand

Introduction

Lichens are plant-like organisms, but their origins are different from other living things. Two types of living things, algae and fungi, coexist symbiotically, coordinated in structure and physiology as one – as a lichen. Algae produce both food by using carbon dioxide (CO_2) from the atmosphere, and water in the process of photosynthesis, resulting in organic matter which feeds fungi. On the other hand, fungi grow in a mycelial manner, which ensures moisture retention, thereby protecting the algae with which they are in symbiosis from harsh environmental conditions such as intense sunlight and heat. Each type of lichen is formed from just one type of fungus and one type of alga. Therefore, there are many different species of lichen. Lichens are consequently diverse, and specific to an area (Boonpragob & Polyaim 2007). They are often found growing on tree trunks and branches, rocks, and moist soils in forests and orchards (Boonpragob 2004).

Lichens have been used since ancient Egyptian times to the present day in many areas of the world, for dyes, food and drugs. Lichens do not have true starch or even cellulose, but there are substances such as lichenin in the cell walls of fungi hyphae which can be used as food. *Cetraria islandica*, or Iceland moss, is processed to remove its bitter taste before cooking (Hale 1983). Lichens have also been used as a soup ingredient by boiling them with milk. People believe that eating lichens as food and using them as drugs can help digestion. Lichens have an ability to form a wide range of secondary metabolites because of their slow growth and tolerance of harsh living conditions. These characteristics give lichen antimicrobial and herbicidal properties (Hale 1983; Manojlovic et al. 2005; Gupta et al. 2007). Worldwide, about 20,000 lichen species have been described so far. Those found in India represent around 10% (2,305 species) of known lichens globally.

In Northern Europe, lichens have been used in bleaching and fermentation. The French perfume industry uses lichen extracts to create pleasant and long-lasting smells. Lichens have also been used to clean (human) hair, and can be used to tell the age of stones and antiquities (Ślusarczyk et al. 2021). *Rocella tinctoria* and other species in this genus give a colour known as orchil, a purple shade. Other types of lichen can produce different dyes, such as red, brown, reddish-brown and yellow. Himalayan lichens include a large number of parmelioid species that provide excellent sources of dyes, and 157 Indian lichen species belonging to 65 genera have dyeing properties (Shukla et al. 2014).

Lichens have another useful characteristic: they readily absorb water, nutritive substances, and gases directly from the atmosphere (Nash 2006). Because they respond directly to atmospheric pollutants, they have been used successfully for biomonitoring air pollution. Biomonitoring approaches using lichens have recently been extended to a suite of other anthropogenic disturbances, such as forest management or climate change (Giordani 2009).

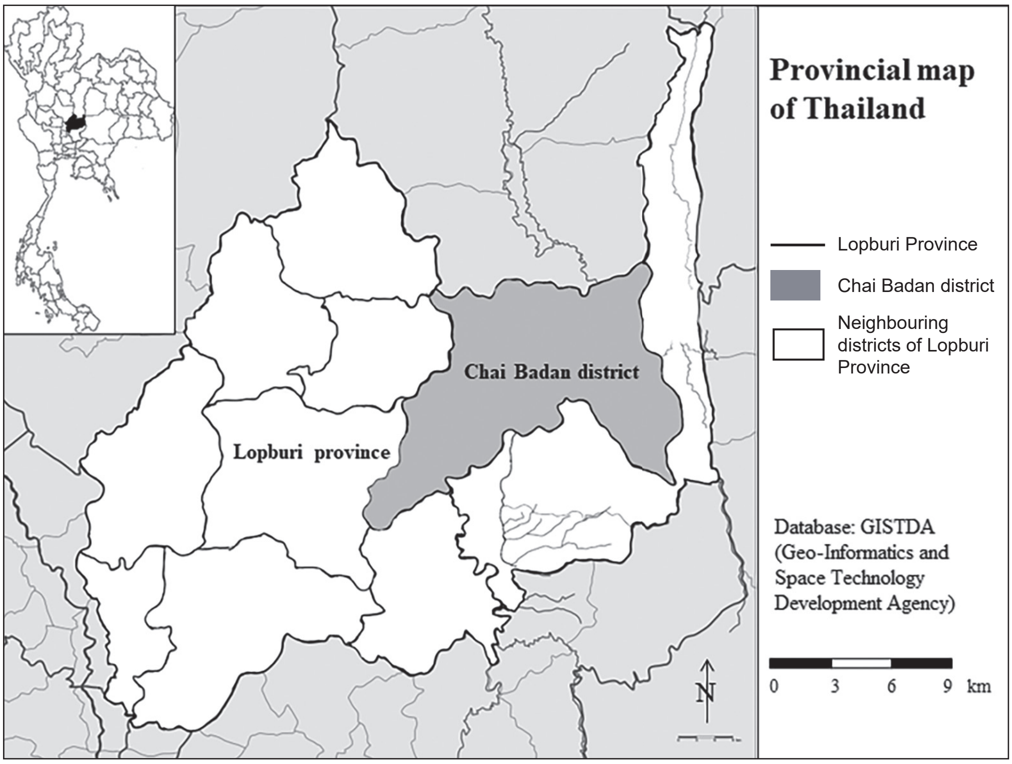

Figure 1 – Chai Badan district, Lopburi province, Thailand.

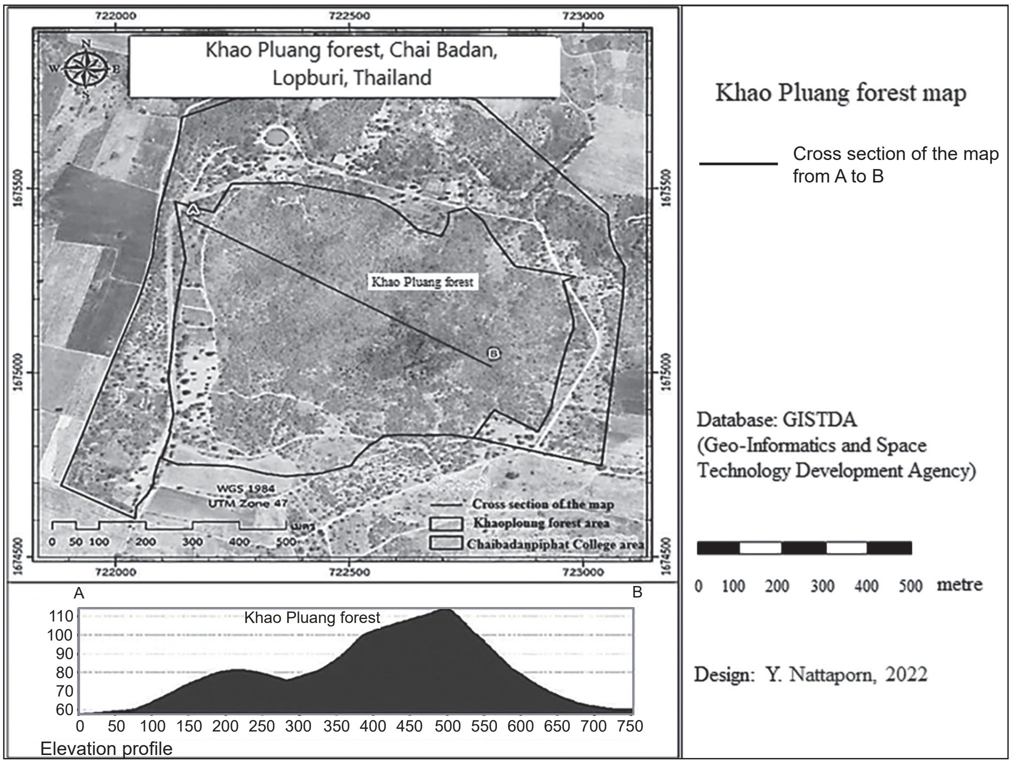

Figure 2 – Khao Pluang forest (black inner line) and Chaibadanpiphat college area (black outer line).

This paper illustrates the biomonitoring of lichens in poorly-known habitats (i.e. in a hazardous area), providing observational data from the physiological to the community levels, and providing the basis for comparable approaches to be extended to a global scale.

Research has found that lichens are susceptible to air pollution (sulfur dioxide (SO_2), fluoride gas (fluorides), and highly oxidizing chemicals such as ozone); they are not equally resistant to air pollution (Nimis & Purvis 2002). This allows us to use lichens on trees, stones, wood etc. as an indicator of air quality in populated areas and elsewhere. For the purposes of initial air-quality monitoring, they can be categorized as weather-resistant, durable and highly durable (Wirth 1988). Further research found that lichen diversity increased along with yearly average rainfall and nitrogen oxide levels, whereas it decreased with increased levels of SO_2 (Giordani 2007).

The study of lichen biodiversity shows that each forest type is characterized by different lichen species. Functional diversity is an important tool to identify the ecological mechanisms shaping the coexistence patterns of species communities and different environmental gradients. However, there is a huge gap in knowledge regarding the ecological mechanisms that shape the composition of lichen communities (Łubek et al. 2020).

The aim of the present study is to construct an ontology for the knowledge of lichens in Thailand by using lichen data from Khao Pluang forest (part of Chaibadan Phiphat College, located in the northern part of Chai Badan district, Lopburi province, Thailand; see Figures 1 and 2), a forest area protected by the Plant Genetic Conservation Project Under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn (referred to from now on as RSPG). Khao Pluang forest is a low mountainous area (60–110 m a.s.l.) of compound forest, which consists mainly of Teng (*Shorea obtusa*), Rang (*Shorea siamensis*) and other deciduous trees. As well as Rang, the forest is home to many other outstanding plant species, including Makha (*Afzelia xylocarpa*), Tako (*Diospyros*), Pai (*Elaeocarpus serratus*), Pek (Pinoideae), Tiw (Figueroa), wild Pakwan (*Melientha suavis* Pierre), and Jujube (*Ziziphus jujuba*).

The RSPG working group on the diversity of lichens would like its knowledge to be disseminated and its approach to serve as a guideline for understanding lichens elsewhere. The findings of this study will be used in establishing a lichen trail in the Khao Pluang area. The study of lichen biodiversity in Khao Pluang forest followed a 1-kilometre nature trail. We found 28 species (LH001-LH028) of lichens, see Table 1. Most of these species belong to the durable group (Boonpeng et al. 2017).

The remainder of this paper is organized as follows. Section 2 describes the materials and methods used (knowledge acquisition, development of the ontological base, sematic search). Section 3 describes the results and presents discussion. Finally, in section 4, we present a number of conclusions.

Materials and methods

An ontology can be defined as the explicit formal specifications of the terms used in a particular domain and the relations among them (Gruber 1993). Constructing a knowledge domain can be conducted by interviewing experts and reviewing the literature. An ontology consists of four attributes: *class, property, facet* and *instance*.

- *Class* refers to the domain of interest (e.g. indigenous knowledge of using lichens as a drug); classes are the focus of most ontologies.
- *Property* covers relations within a class (e.g. *can be used as*). Properties describe various features and attributes of a class. For example, *Lichens found in the northern of Thailand can be used as a drug because of its digestive properties.*
- *Facets* are the restrictions on relations or properties. We can explain restrictions by using the relationships: Is an item (IS-A), part of (p/o) or an attribute of (a/o), e.g.
  - *to be used as food IS-A lichens' properties* or *to be used as drug IS-A lichens' properties*;
  - *digestive properties is p/o drug's propertie*s or *purple colour is a/o dyes colour*;
- An *instance* refers to actual data, recorded in a record or table.

Classes comprise all the terms in a domain of discourse, which are then transferred into formal explicit descriptions (e.g. sources of dyes, digestive properties, air pollution indicator).

Finally, a knowledge base is constructed by connecting the ontology (the combination of classes, properties and facets) with a set of individual instances of classes.

Recently, ontologies have been moving from the desktops of domain experts to become more widely accessible through the semantic web. Many research areas have developed their own ontologies (e.g. ontologies for agriculture, disease, biomedical investigation, and genes). In agriculture, ontology can be applied for soil- and seed-selection processes; for disease control and treatment; or for smart farming (Visutsak 2021; Bonacin et al. 2016; Li et al. 2013; Bhuyan 2021; Goldstein 2021). The disease ontology semantically integrates disease and medical vocabularies through extensive cross mapping of terms (Kurbatova & Swiers 2021; Schriml 2022). The ontology for biomedical investigation is an integrated ontology for the description of the life sciences and clinical investigations. In practice, it represents a collaborative effort to address the need for consistent descriptions of gene products across databases (Bandrowski et al. 2016; Hongjiea et al. 2019), covering information about biological processes, cellular components and molecular functions (Suntisrivaraporn 2013; Zhanga et al. 2020; Nie et al. 2021).

The most important aspects of our database are the stored knowledge on lichens generally, the latitude and longitude of particular lichens at Khao Pluang forest, and images of them. Figure 3 shows the three main stages of the ontology-development framework.

Knowledge acquisition

In this step, we collected knowledge of lichens found at Khao Pluang forest from the experts who work at RSPG and are familiar with a lichen trail in the

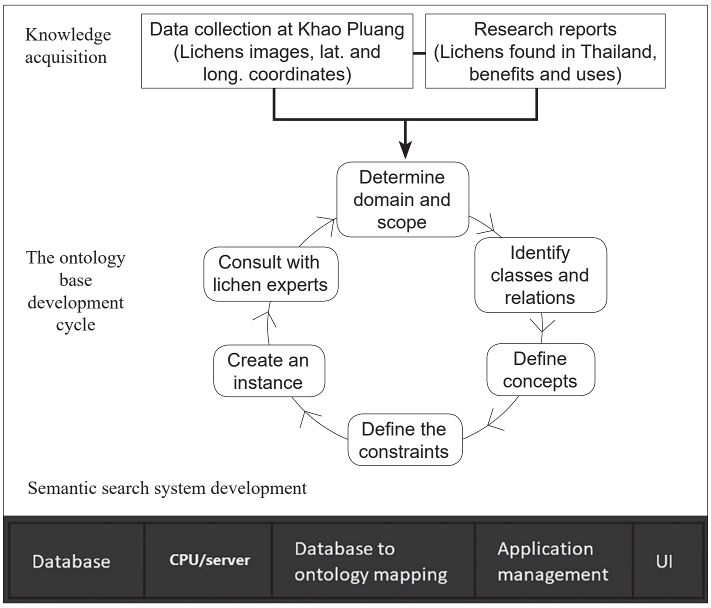

Figure 3 – Framework for development of the ontology.

Figure 4 – Data collection, Khao Pluang forest. © P. Khamweera

Table 1 – Lichens used in this study found in Khao Pluang Forest, Chaibadanpiphat College.

Sample number	Lichen	Sample site	
		Latitude (North)	Longitude (East)
LH001	*Amandinea* sp.	N 15°08′45.27″	E 101°04′10.41″
LH002	*Gyalecta* sp.	N 15°08′45.27″	E 101°04′10.41″
LH003	*Graphis* sp.	N 15°08′45.27″	E 101°04′10.41″
LH004	*Pyrenula* sp.	N 15°08′45.27″	E 101°04′10.41″
LH005	*Porina* sp.	N 15°08′45.27″	E 101°04′10.41″
LH006	*Bacidia* sp.	N 15°08′45.27″	E 101°04′10.41″
LH007	*Pyxine cocoes*	N 15°08′45.27″	E 101°04′10.41″
LH008	*Hyperphyscia adglutinata*	N 15°08′45.27″	E 101°04′10.41″
LH009	*Phydcia undulata*	N 15°08′45.27″	E 101°04′10.41″
LH010	*Graphis* sp.	N 15°08′45.27″	E 101°04′10.41″
LH011	*Chrysothrix xanthina*	N 15°08′45.27″	E 101°04′10.41″
LH012	*Dirinaria picta*	N 15°08′45.27″	E 101°04′10.41″
LH013	*Lecanora argentata*	N 15°08′45.27″	E 101°04′10.41″
LH014	*Lacanora helva*	N 15°08′45.27″	E 101°04′10.41″
LH015	*Pyrenula* sp.	N 15°08′45.27″	E 101°04′10.41″
LH016	*Fissurina* sp.	N 15°08′45.27″	E 101°04′10.41″
LH017	*Pyxine* sp.	N 15°08′45.27″	E 101°04′10.41″
LH018	*Pyrenula anomala*	N 15°08′45.27″	E 101°04′10.41″
LH019	*Peltula* sp.	N 15°08′45.27″	E 101°04′10.41″
LH020	*Peltula obscurans*	N 15°08′45.27″	E 101°04′10.41″
LH021	*Amandinea* sp.	N 15°08′45.27″	E 101°04′10.41″
LH022	*Caloplaca* sp.	N 15°08′45.27″	E 101°04′10.41″
LH023	*Pyxine* sp.	N 15°08′45.27″	E 101°04′10.41″
LH024	*Parmotrema praesorediosum*	N 15°08′45.27″	E 101°04′10.41″
LH025	*Pyxine copelandii*	N 15°08′45.27″	E 101°04′10.41″
LH026	*Lecanora subimmersa*	N 15°08′45.27″	E 101°04′10.41″
LH027	*Lecanora* sp.	N 15°08′45.27″	E 101°04′10.41″
LH028	*Moneralechia bodies*	N 15°08′45.27″	E 101°04′10.41″
LH029	*Lecanora pseudistera*	N 15°08′45.27″	E 101°04′10.41″

area. We also conducted a thorough search of the literature for information on lichens found in Thailand. The lichen images (Figure 4) were collected during a trial field trip, and we took some lichen samples for laboratory testing; the location of the lichens was identified using GPS equipment (Figure 4). Table 1 presents a list of the lichens found in Khao Pluang forest.

The ontology-base development cycle

After gathering the knowledge and verifying its correctness, we developed the knowledge ontology, adapting the system used in our earlier work (Visutsak 2021) on durian pests and disease control. The development of the ontology base comprises 6 consecutive steps.

1. Determining the domain and scope of the ontology-based system – in this instance the domain knowledge of lichens in Thailand, by using the data on lichen collected from Khao Pluang forest (as in

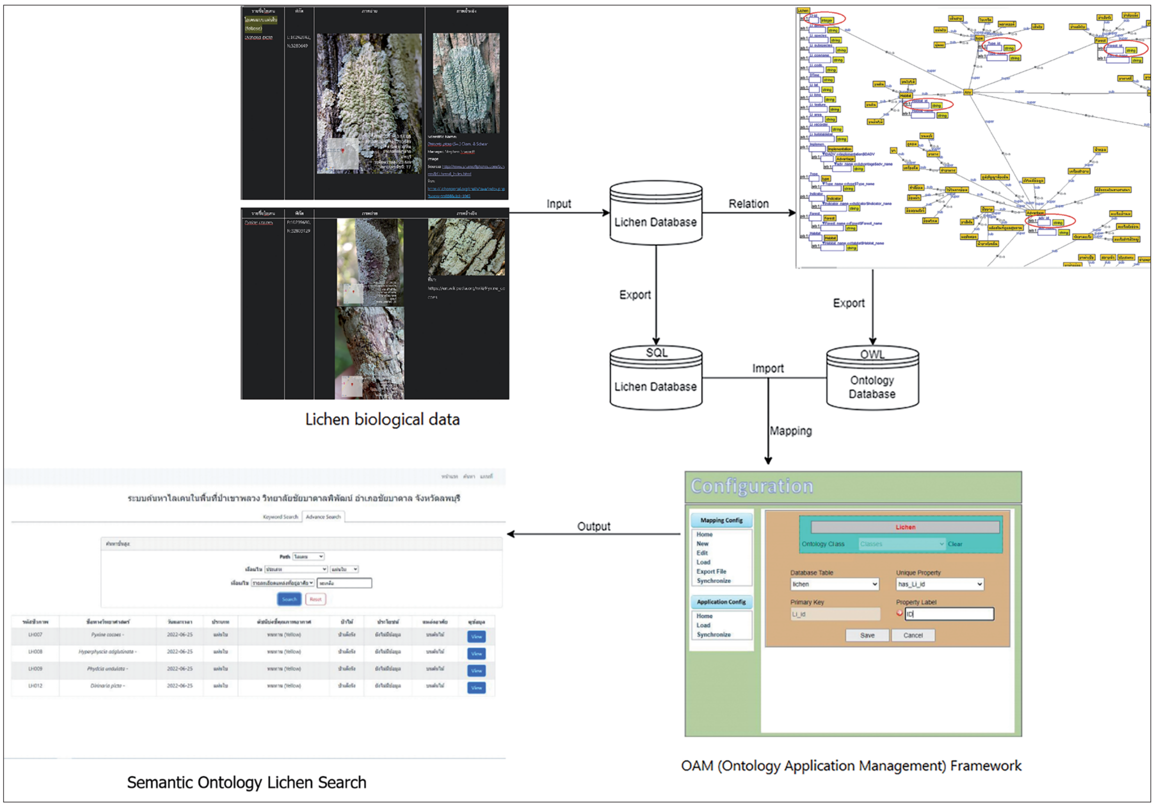

Figure 5 – The system architecture.

Table 1), images of the lichens, and their uses and benefits as detailed in the literature.

2. Identifying classes and relations. The ontological knowledge consists of 6 main classes: 1) scientific name, 2) lichen type, 3) date found, 4) uses of the lichen, 5) importance as air pollution indicator, and 6) specific features of individual lichens.
3. Defining the ontology property. We categorized the properties into 3 types (IS-A, p/o, and a/o).
4. Defining the constraints. For example, the *habitat* class has 4 constraints: rock, leaf, branch and soil.
5. Creating an instance. For example, the biological ID is the instance on the lichen's label.
6. Double-checking with experts that our method was appropriate.

We investigated two well-known ontology editors, Protégé (Musen 2015) and Hozo (Riichiro 2007), and chose Hozo for this work. Figure 5 shows the overall system architecture of our work. Table 2 shows the sample lichens implemented in the Hozo editor.

The semantic search system

After checking with the experts once again, and checking the references to the literature on lichens, the last phase was to develop the semantic search system. We used the Ontology Application Management Framework, OAM (NECTEC 2012), from NECTEC. The OAM consists of 2 main components:

1. The Database-to-Ontology Mapping Component. We used OWL (Web Ontology Language) for mapping data from the database to the ontology base. The results of the mapping were transformed into RDF (Resource Description Framework) format. The OWL for lichen data is shown in Figure 6.
2. The Search Configuration Component. This user interface (UI) can be used as the query component and shows the query results. In the web-based GUI, the user can select multiple conditions (e.g. dyed + coloured); the query results are shown on the screen.

Table 2 – Lichens as an ontological class. p/o – part of, a/o – an attribute of, Li – Lichens.

Ontology Class	**Relation Type**	**Lichen Database**
Lichen		Lichen bilogical data
	a/o	Li_id
	a/o	Li_genus
	a/o	Li_species
	a/o	Li_subspecies
	a/o	Li_com_name
	a/o	Li_code
	a/o	DTime
	a/o	Li_lat
	a/o	Li_long
	a/o	Li_feature
	a/o	Li_area
	a/o	Li_recorder
	a/o	Li_habitatdetail
	p/o	Implement
	p/o	Type_id
	p/o	Indicator_id
	p/o	Forest_id
	p/o	Habitat_id

```
<owl:Class rdf:ID="Advantage">
    <rdfs:label>Advantage</rdfs:label>
    <rdfs:subClassOf rdf:resource="#Any" />
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:cardinality>
            <owl:onProperty rdf:resource="#has_adv_id" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#has_adv_id" />
            <owl:allValuesFrom rdf:resource="#string" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:cardinality>
            <owl:onProperty rdf:resource="#has_adv_name" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#has_adv_name" />
            <owl:allValuesFrom rdf:resource="#string" />
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Figure 6 – The OWL (Web Ontology Language) used in this work.

Results and discussion

The program works with a search engine that also displays a system-generated map with the location, a picture and a brief description of the lichen in Khao Pluang forest.

We evaluated the system by asking the lichen and ontology experts to assess it using a 10-question questionnaire based on 5 terms used in the Software Usability Measurement Inventory (SUMI) (Kirakowski 1995), see Table 3:

1. *Efficiency:* used to evaluate the overall performance of the software, such as the accuracy of the query results and the execution time.
2. *Affect:* used to evaluate the user's impression of using the software.
3. *Helpfulness:* used to assess how the system can help the user, or the benefits of the system.
4. *Control:* used to evaluate the usability of the system.
5. *Learnability:* used to evaluate the ease of use or user-friendly features.

Table 3 – The assessment of the lichen ontology using SUMI.

	Mean	S.D.	Quality level
Efficiency	2.31	0.7	Medium
Affect	2.35	0.76	Medium
Helpfulness	2.43	0.67	Good
Control	2.63	0.55	Good
Learnability	2.39	0.71	Good

Conclusion

In this paper, we used data on lichens collected from Khao Pluang forest to construct an ontology of the domain knowledge. A major benefit of our system is that it can be used for compound search queries (i.e. using multiple words). The query results returned are based on the connections between classes (i.e. relations) in the domain knowledge (domain ontology or domain of interest). The principal contributions of this work are the extent of the stored knowledge on lichens (as air pollution indicators; uses for drugs, food, dyes; sources for antibiotic substances and extracts), the latitude and longitude of lichens at Khao Pluang forest, and the lichen images (with the corresponding ID of lichens found at Khao Pluang forest). The users' assessment based on SUMI shows that our system yields medium-quality efficiency and effectiveness, and good-quality helpfulness, control and learnability.

Acknowledgements

This work was supported in part by the Plant Genetic Conservation Project under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn (RSPG) and King Mongkut's University of Technology North Bangkok.

References

Bandrowski, A. et al. 2016. The Ontology for Biomedical Investigations. *PLoS ONE* 11(4): e0154556. Doi: 10.1371/journal.pone.0154556

Bhuyan, B.P. 2021. An Ontological Knowledge Representation for Smart Agriculture. *IEEE International Conference on Big Data (Big Data)*: 3400-3406. Doi: 10.1109/BigData52589.2021.9672020

Bonacin, R., O.F. Nabuco, I.P. Junior 2016. Ontology models of the impacts of agriculture and climate changes on water resources: Scenarios on interoperability and information recovery. *Future Generation Computer Systems* 54: 423–434. Doi: 10.1016/j.future.2015.04.010

Boonpeng, C., W. Polyiam, C. Sriviboon, D. Sangiamdee, S. Watthana, P.L. Nimis & K Boonpragob 2017. Airborne trace elements near a petrochemical industrial complex in Thailand assessed by the lichen Parmotrema tinctorum (Despr. ex Nyl.) Hale. *Environmental Science and Pollution Research* 24: 12393–12404.

Boonpragob, K. & Polyaim, W. 2007. Ecological groups of lichen along environmental gradients on two different host tree species in the tropical rain forest at Khao Yai National Park, Thailand. *Bibliotheca Lichenologica* 96: 25–48.

Boonpragob, K. 2004. Lichens. In Jones, E.B.C., M. Tanticharoen, K.D. Hyde (eds.), *Thai fungal diversity*, BIOTEC: 79–85. Thailand.

Giordani, P. 2007. Is the diversity of epiphytic lichens a reliable indicator of air pollution? A case study from Italy. *Environmental Pollution* 146: 317–323.

Giordani, P. 2009. Lichen Diversity and Biomonitoring: A Special Issue. *Diversity* 11: 171. Doi: 10.3390/d11090171

Goldstein, A. 2021. A Framework for Evaluating Agricultural Ontologies. *Sustainability* 13: 6387. Doi: 10.3390/su13116387

Gruber, T.R. 1993. A translation approach to portable ontology specifications. *Knowledge acquisition* 5(2): 199–220.

Gupta, V.K., M.P. Darokar, D. Saikia, A. Pal, A. Fatima & S.P.S. Khanuja 2007. Antimycobacterial activity of lichens. *Pharmaceutical Biology* 45(3): 200–204. Doi: 10.1080/13880200701213088

Hale, M.E. 1983. The Biology of Lichens, 3rd ed.: 120–137.

Hongjiea, P., Y. Zhu, S. Yang, Z. Wang, W. Zhou, Y. He & X. Yang 2019. Biomedical ontologies and their development, management, and applications in and beyond China. *Journal of Bio-X Research* 2(4): 178–184. Doi: 10.1097/JBR.0000000000000051

Kirakowski, J. 1995. Evaluating Usability of the Human-Computer Interface. In: Pfleger S, J. Gonçalves & K. Varghese (eds.), Advances in Human-Computer Interaction – Human Comfort and Security. *Research Reports Esprit* 1: 21–32. Doi: 10.1007/978-3-642-85220-6_2

Kurbatova, N. & R. Swiers 2021. Disease ontologies for knowledge graphs. *BMC Bioinformatics* 22: 377. Doi: 10.1186/s12859-021-04173-w

Li, D.Y., L. Kang, X. Cheng, D.L. Li, L.Q. Ji, K. Wang & Y. Chen 2013. An ontology-based knowledge representation and implement method for crop cultivation standard. *Mathematical and Computer Modelling* 58(3–4): 466–473. Doi: 10.1016/j.mcm.2011.11.004

Łubek, A., M. Kukwa, B. Jaroszewicz & P. Czortek 2020. Identifying mechanisms shaping lichen functional diversity in a primeval forest. *Forest Ecology and Management* 475: 118434. Doi: 10.1016/j.foreco.2020.118434

Manojlovic, T.N., M. Novakovic, V. Stevovic & S. Solujic2005. Antimicrobial activity of three Serbian Caloplaca, *Pharmaceutical Biology* 43(8): 718–722. Doi: 10.1080/13880200500387257

Musen, M.A. 2015. The Protégé project: A look back and a look forward. *AI Matters. Association of Computing Machinery Specific Interest Group in Artificial Intelligence* 1(4): 4–12. Doi: 10.1145/2557001.25757003

Nash, T.H. 2006. Lichen Biology. Leiden, UK.

NECTEC 2012. Ontology Application Management Framework (OAM). Available at: http://lst.nectec.or.th/oam (accessed 3/3/2023)

Nie, Z.Y., Y.-H. Li, L. Li & X. Zhao 2021. Characterization and transcriptomic analysis of Streptococcus thermophilus strain EU01 promoted by Eucommia ulmoides Oliv. Extract. *ScienceAsia* 47: 19–29. Doi: 10.2306/scienceasia1513-1874.2021.002

Nimis, P.L. & W.O. Purvis 2002. Monitoring lichens as indicators of pollution. An introduction. In: Nimis P.L., C. Scheidegger & P. Wolseley (eds.), *Monitoring with Lichens e Monitoring Lichens*: 7–10. Kluwer, Dordrecht.

Riichiro, M. 2007. The model of roles within an ontology development tool: Hozo. *Applied Ontology* 2(2): 159–179.

Schriml, L.M. 2022. The Human Disease Ontology 2022 update, *Nucleic Acids Research* 50 (D1): 1255–1261. Doi: 10.1093/nar/gkab1063

Shukla, P., D.K. Upreti, S. Nayaka & P. Tiwari 2014. Natural dyes from Himalayan lichens. *Indian Journal of Traditional Knowledge* 13 (1): 195–201.

Ślusarczyk, J., E. Adamska & J. Czerwik-Marcinkowska 2021. Fungi and Algae as Sources of Medicinal and Other Biologically Active Compounds: A Review. *Nutrients*. 13(9): 3178. Doi: 10.3390/nu13093178.

Suntisrivaraporn, B. 2013. Finding all justifications in Snomed ct. *ScienceAsia* 39: 78–89. Doi: 10.2306/scienceasia1513-1874.2013.39.078

Visutsak, P. 2021. Ontology-Based Semantic Retrieval for Durian Pests and Diseases Control System. *International Journal of Machine Learning and Computing* 11(1): 92–97. Doi: 10.18178/ijmlc.2021.11.1.1019

Wirth, V. 1988. Phytosociological approaches to Air Pollution Monitoring with Lichens. In: Nash III T.H. & V. Wirth (eds.), *Lichens, Bryophytes and Air Quality* 30: 91–107. Berlin-Stuttgart. 30: 91–107.

Zhanga, Y., M. Ma, H. Huang, Y. Zhang & G. Zhao 2020. Transcriptome analysis of 20-hydroxyecdysone induced differentially expressed genes in the posterior silk gland of the silkworm, Bombyx mori. *ScienceAsia* 48: 171–180. Doi: 10.2306/scienceasia1513-1874.2022.025

Authors

Pemika Khamweera[1]

is at the Faculty of Science and Technology, Phranakhon Rajabhat University, where she is Assistant Professor in Biology.

Natthawut Chaloyard[2]

has a BSc in Computer Science from the Department of Computer and Information Science.

Anawat Klaysood[2]

has a BSc in Computer Science from the Department of Computer and Information Science.

Somkid Soottitantawat[1]

is with the Faculty of Science and Technology Phranakhon Rajabhat University, where she is Assistant Professor in Computer Science.

Wetchasart Polyiam[3]

is a Lecturer in the Department of Biology, Faculty of Science.

Supattara Phokaeo[3]

works for the Lichen Research unit, Department of Biology.

Nikorn Sutthisangiam[2]

is Assistant Professor in the Department of Computer and Information Science.

Porawat Visutsak[2]

was a Senior Visiting Scholar in the Computer Science and Technology Program, School of Computer Science and Technology, Beijing Institute of Technology, under the China Scholarship Council (CSC). He is now Associate Professor in the Department of Computer and Information Science.

[1] Faculty of Science and Technology, Phranakhon Rajabhat University, Bangkok 10220, Thailand
[2] Department of Computer and Information Science, Faculty of Applied Science, KMUTNB, Bangkok 10800, Thailand
[3] Faculty of Science, Ramkhamhaeng University, Bangkok 10240, Thailand