Ontology-Based Semantic Search Development on Lanna King History Using Buddhist Temple and Related Documents

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ABSTRACT

Historical information plays a significant role in explaining and supporting the story of what had happened in the past. Studying history helps us to understand some changes and how the society we live in came to be. The objective of this study is to present the methodology for developing a knowledge base of Lanna history with respect to the Lanna kings appeared in Buddhist temple and related documents by using ontology techniques and to develop the application as a semantic search system. Ontology technique helps identify key concepts and relationships among the concepts in the domain. It represents the relationship between king, temple, historical site, and year. The process of research started with collecting temple data located in the upper northern part of Thailand, then creating a database storing data. We used data obtained from previous research on historical relation extraction, consisting of relationships of Lanna king and Buddhist temples. The design and development of ontology is done by the Hozo ontology editor tool. The result is the Lanna Historical Ontology, consisting of 8 major classes. After that, the designed ontology is transformed into OWL, then imported to OAM program for database mapping and creating or developing the semantic search system. From the experiment, we designed 18 queries categorized into four groups to evaluate the designed semantic search system based on the measures of precision, recall and F-measure. The result showed that the average values of precision, recall and F-measure of semantic search are 100%, 80.47%, and 89.18% respectively.

Keywords: Semantic Search, Ontology, Historical Lanna Kingdom, Historical Knowledge Base

INTRODUCTION

The study of history is important for society. It was what helped humans in that society to know the story of what has happened in the past as well as their own culture. From past to present, historical evidences have existed in the form of text documents, remains of historical sites, recorded data, pictures, artifacts, etc. Ancient kingdoms mostly have left behind impressive landmarks and historical sites, which remained till today, such as pagodas, chapels, Buddha paintings, and so on. Those of artefacts and remains can be used for studying history and what may happened in the past by searching for some evidences, analyzing contents and corroborating with

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further evidences. By using those evidences and the interpretation of past events, it can hold some significance for the present.

Lanna Kingdom is one of the most important regions of Siam (or Thailand). It was established in 1296 by King Mangrai, who founded Chiang Mai as the capital city, government and culture center. Lanna kingdom is located in the upper northern part of Thailand and used to control some border lands of Laos and Burma. Later in 1396, Lanna Kingdom became part of Thailand (Penth, 2001). Thailand is referred to as "The Land of Buddhism", which is one of the best destinations for people who are interested in the teachings of Buddhism. Therefore, Buddhism has been closely related to Thai people since 1257 during the Sukhothai Kingdom, which was also known as the "Golden Age of Buddhism". Since then most of Thai people became Buddhists and believed in Buddhist's teachings (Piyabhani, 2016). Lanna Kingdom allied with the Sukhothai Kingdom, hence Buddhism also flourished in Lanna (Wonglangka and Han, 2018).

A Buddhist temple is a place to perform sacred rituals and practices, and also a place for education and vocational training. From past to present, Buddhist temples and religious buildings are designated to be the center of the community which were maintained by kings, noble citizens, rich merchants, and the general public. In ancient times, the construction of temples was the role of the Lanna king to provide a place to perform religious rituals and uphold Buddhism. Thus, temples and towns were created simultaneously with all being related to the history in some way. For example, Chiang Man temple, the oldest temple in Chiang Mai, was built as the first temple of the city when King Mangrai decided to build a new city of the Lanna Kingdom. The above information shows that temples play a significant role as a close link in keeping the people together as a nation and being the center of the Thai way of life. Buddhist temples and remains could become a part of historical documentaries for future studies and further interpretation.

From the study, the history of temples and their related artifacts have been studied and written about by experts, then stored in a book form, while some were transformed into a digital format and published on websites. However, most of the documents are in picture and text, which are unstructured. The information can only be gleaned manually by experts from the original documents, in which it is time consuming and causes delays in the search. From our previous research (Chantaraj et al., 2019), using the historical concept, the name of kings, historical events, and valuable artifacts can denote the historical point of view, which applied the information extraction technique for historical relation extraction from Buddhist temple documents of the Lanna Kingdom. The results from our previous study, including the relationships of the name of the kings who built the temple, the king who created or restored historical sites located within its ground and stated the Buddhist era the temple was built, were stored in a database. They can support a chronological search on the history of the Lanna kingdom to be applied to the present. This allows the correlation of the location, period and the name of the king enabling the possible indication of who built or restored which temple during what period, and provide historical knowledge that can be utilized effectively in the future.

Presently, the web search systems that are based on keyword searches have low precision as a result of dealing with the ambiguity of natural language. Users may

have to do several crawling on the search result before being able to find the needed information which caused delays in the search. In addition, the websites have no mechanisms to present the information in a chronicle way and do not meet the user's requirement for the needed semantic search. Thus, to deal with the limitation of the current web searching, the ontology technique is used to increase the performance of the semantic search.

Ontology is the technique used to manage and present knowledge to describe the concept and details of knowledge which includes hierarchical structure of relations (Gruber, 1995; Hendler, 2001). This study uses ontology for the conceptualization process of domain knowledge focus of Lanna history, the aspect of king history in Buddhist temple and related documents. The result of well-constructed ontology helps to reveal relationships between the temples, historical sites, kings and year. Ontology-based semantic search will enhance the efficiency of the searching process.

In this research, we have used the results from our previous research (Chantaraj et al., 2019) and also gathered additional information from relevant sources. The objective of this study is to develop a semantic search on Lanna King History from Buddhist temples and related documents by using the ontology principle. We focus on designing and building an ontology for the Lanna history domain. The result of this study includes a prototype of the semantic web for Lanna kingdom history and events, which can be searched and accessed historical events data in the aspects of temples, historical sites, king's names, and chronological events. It provides a knowledge base that is useful in a historical sense that people in the society can recognize and understand. This would show stability, prosperity and peaceful coexistence within society, with the monarchy being the center of the public's faith from past to present.

The remainder of this paper is organized as follows. First, we discuss some related works in the field of historical knowledge and ontology. Then, we describe the method to design and development the ontology in the proposed system, lastly, report and discuss the experimental results, and conclude by summarizing the key points of our work and presenting future directions.

RELATED WORKS

The semantic web is an extension of the current web where data is linked to provide more defined meaning in order for humans and computers to work together. The main method for this is ontology (Berners-Lee et al., 2001). Ontology is one of the solutions that can lead the users to correct answers to their search. There are several works of culture and history that have applied ontology technique in applications. For example, the construction of ontology which compiled the knowledge around the cultural heritage related to a region Cantabria in Spain was done by using semantic web technologies to make integration of the information from a variety of online sources, such as institutional archives, web pages, relational databases. If data are not accurate or incomplete, domain experts manually filled these templates in order to complement existing knowledge or contribute some new ones. The ontology based semantic search web allows easy access to the contents (Hernández et al., 2008). The design and implementation of ontology representing

knowledge embedded in Yorùbá Cultural Heritage (YCH) to elicit embedded knowledge in the museums and monuments of Yorùbá antiquities and their narratives was established. The results of this study have enabled the sharing of information between different agents and interfacing users and data on the semantic web of YCH. In addition, the principle and methodology presented can be adapted to African heritage museums, monuments, memorabilia, library, iconic, and archival resources reducing the same to digital resources and made accessible for a global audience using Information and Communication Technologies (Hassan et al., 2013). A similar research presented ontology based conceptual framework for storage and retrieval of Digitized Museum Artifacts. It supported semantic retrieval by combining ontological concepts, visual and textual features automatically extracted from images and their textual descriptions. The Ontology-based framework partially alleviates the limitations entailed by the high cost of manual annotation through automatic generation of semantic annotation thus, enabling a realistic approach to effective image access at the semantic level (Sharma and Siddiqui, 2016). In historical work, the processes during ontology building in history and historical document retrieval based on the event from battles and operations in the Vietnam War can facilitate and support the query and retrieval of historical documents (Ramli and Noah, 2016).

In addition, there are some works that used information technology and multimedia to present information obtained from human or expert analysis so it can be accessed and used easily. For example, a model to explain the historical event of temporal data using a timeline visualization technique was introduced (Hasan et al., 2013). Furthermore, an analysis of change types in historic regions and applied ontology time series to create an application for information retrieval and visualization in a semantic cultural heritage portal. This application was used in a case study to create a complete model of the changes of the Finnish municipalities (Kauppinen et al., 2008). Moreover, the web-based system for ground truth generation to help historians and computer scientists collectively record annotate historical documents were presented (Biller et al., 2013).

From all the related work that is cited above, we have chosen to apply ontology technique for creating knowledge base to support the semantic search of the history of Lanna kingdom.

MATERIALS AND METHODS

This section describes how to develop a semantic search for the Lanna kingdom history using ontology technique. The proposed process displayed in Figure 1 is based on applying the ontology principles. The process can be divided into three main steps which are knowledge acquisition, ontology design and development, and ontology application management, which can be described in details as follows.

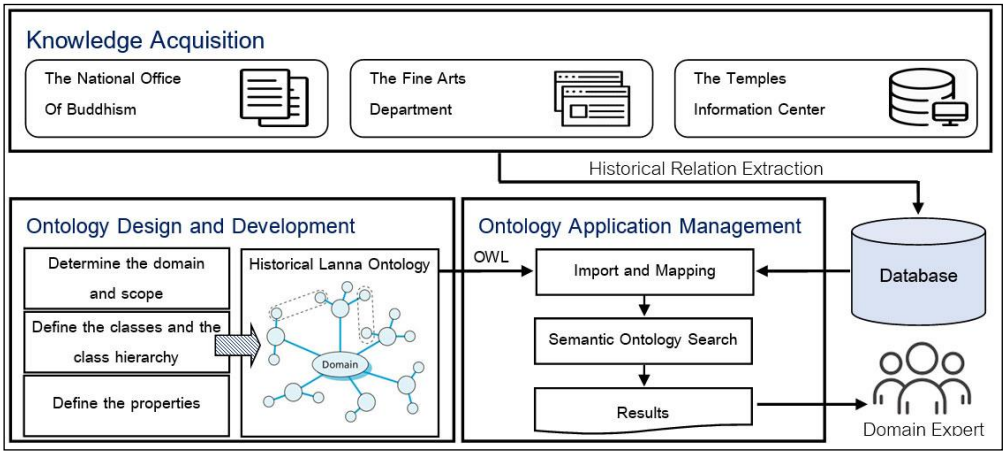


Figure 1 The proposed process for developing ontology-based semantic search for the history of Lanna kingdom.

Knowledge Acquisition.

Historical evidences from Buddhist temples in Thailand are collected by the National Office of Buddhism, the Fine Arts Department and Temples Information Center. Therefore, we have asked for permission to use relevant information and data to collect the historical aspects of temples. In this study, we only chose temples that were created during the Lanna period between 1261 and 1939 (Ongsakul, 2005). The 1,093 temples located in the upper northern part of Thailand, consisting of Chiang Mai, Chiang Rai, Lamphun, Lampang, Mae Hong Son, Phayao, Phrae, and Nan from 8 provinces. In addition, we also used the results from the historical relation extraction of our previous research (Chantaraj et al., 2019). As a result, we create a database to systematically store Lanna history information. It was created by using MySQL in order to prepare data for the data mapping with ontology in the next step.

Ontology Design and Development.

This section describes the design and development of the Lanna ontology using the Hozo (Kozaki et al., 2000), an ontology editor tool. The design and development of our ontology is based on the following steps.

1) Determine the domain and scope

Our proposed ontology is developed by defining its domain and scope through questions about the Lanna Kings to denote the historical viewpoints, consisting of relationships of the king who built the temple, created or restored the historical site located within its grounds, and the year the temple was built. Answering to these questions might alter or change the design process which might help limit the scope of the ontology.

2) Define the classes and the class hierarchy

Concepts or classes of domain knowledge are enumerated for integrating in Lanna king history ontology in this step. The knowledge domain in this study covers the information about the history the temple and king in the Lanna kingdom. All defined concepts are used in the knowledge base and linked to the relevant information. The ontology developed in this research includes 8 major classes, as shown in Table 1.

Table 1 The classes of Lanna historical ontology.

Classes	Description
Era	The time in the Lanna period, in which this era was divided into 3 periods; Lanna Kingdom during Mangrai Dynasty, Lanna during the Burmese Occupation and Lanna during Vassal Statehood of Siam.
King	A list of name of the King in Lanna kingdom (total 42 kings (Ongsakul, 2005)), year of reigns and era of reigns.
Temple	A Buddhist temple is a place to perform sacred rituals and practices and also a place to store valuable artifacts. Most of the outstanding historical artistic artifacts were found or discovered in temples, showed significant national events and historical evidences.
History	The historical information of the temple establishment such as the origin, built by which king and year built.
HitoricalSite	Types of historical site such as pagoda, chapels, etc.
HistoricalSite_list	List of the historical sites within temple grounds, which are built or restored by Lanna king.
Relation_type	The keywords that indicate the relationship between the king, temples, and historical sites such as create, built, restore and renovate, etc. For example, which king built the temple, created or restored which historical site, and in which Buddhist era the temple was built.
Location	This class represented the location of the temples consists of: Tambon is a local governmental unit in below Amphur and province, Amphur is the second level administrative subdivision of local government, and Provinces are parts of Thailand.

The next step is a process of assigning the superclass/subclass relationships of classes represented in hierarchical form, i.e. IS-A relationship (or subclass-of). For example, pagoda, chapel, main hall, scripture hall, and wall, etc. All concepts are defined as subclasses of historical site concept, as shown in Figure 2.

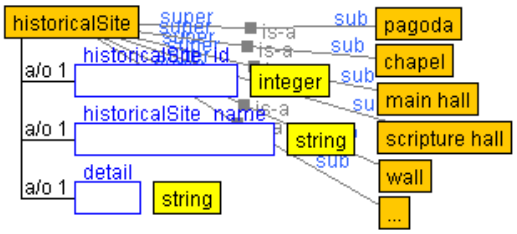


Figure 2 An Example of relationship of class/subclass.

3) Define the properties

Property is the specific characteristic of an object in any class. In this step, the properties of the classes were assigned. There are two types of properties to be defined: data properties (attribute-of) and object properties (part-of). The data properties are used to describe the data type of the classes such as string, integer, float, etc. For example, the data properties of the "hs_id" is an integer and "hs_history" is a string. The object properties are defined to describe the relationship of two related classes in ontology. For example, “has_king” is used to relate the “history” concept to the “king”, as shown in Figure 3.

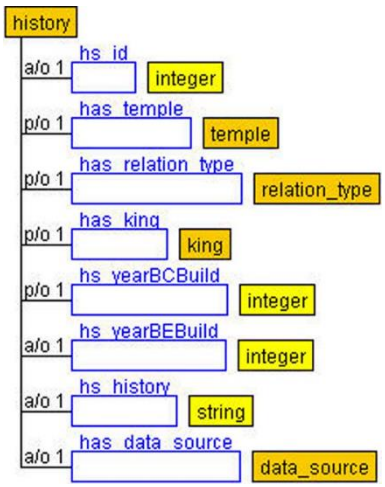


Figure 3 The History Class and its Properties.

Figure 3 displays the detail of the History class which is about the historical information of the temple. The data properties and relationships between the History class and other classes are defined via the object properties, as shown in Table 2.

Table 2 The properties of history of the temple.

Name	Type	Description
hs_id	Datatype Property	Integer
has_temple	Object Property	Related to the Temple class
has_relation_type	Object Property	Related to the Relation Type class
has_king	Object Property	Related to the King class
has_yearBCBuild	Datatype Property	Integer
has_yearBEBuild	Datatype Property	Integer
hs_history	Datatype Property	String
has_data_source	Object Property	Related to the Data Source class

The result of this process is the Lanna Historical Ontology with the 8 main classes. The relationship between classes and subclasses in the ontology is shown in Figure 4.

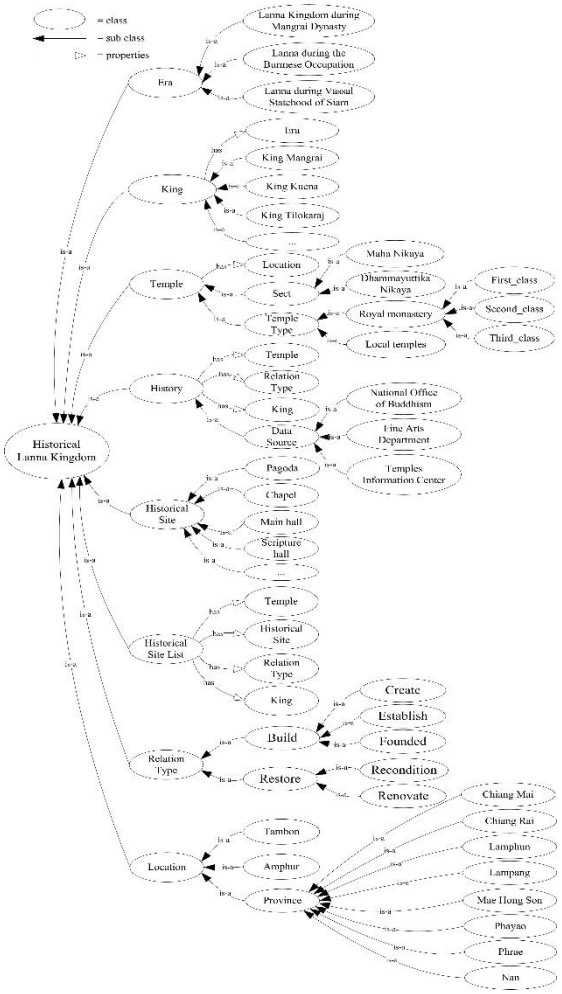


Figure 4 The relationship between classes and subclasses in Lanna king history ontology.

In this section, the Lanna historical ontology schema is exported from Hozo to OWL (Web Ontology Language) format (Gouveia and Cardoso, 2009) which is the standard language for creating ontology as shown in Figure 5. The next step, OWL will be used together with importing and mapping with a database for semantic searching.

```
<owl:Class rdf:ID="history">
    <rdfs:label>history</rdfs:label>
    <rdfs:subClassOf rdf:resource="#Any" />
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/
            <owl:onProperty rdf:resource="#has_hs_id" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#has_hs_id" />
            <owl:allValuesFrom rdf:resource="#integer" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/
            <owl:onProperty rdf:resource="#has_has_temple" />
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#has_has_temple" />
            <owl:allValuesFrom rdf:resource="#temple" />
        </owl:Restriction>
    </rdfs:subClassOf>
```

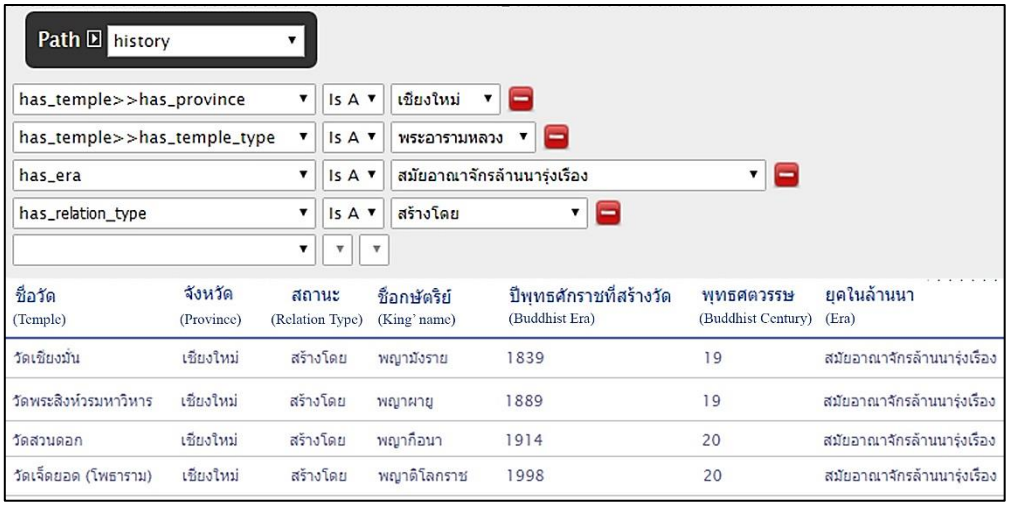
Figure 5 The OWL (Web Ontology Language) format.

Ontology Application Management

In this step, we use Ontology Application Management (OAM) framework as a development platform for simplifying the creation and adoption of ontology-based semantic web application, which is developed by NECTEC (Buranarach et al., 2016). It is used to connect the knowledge base with the designed ontology for searching the desired information requested by the user. With the support of OAM, we imported the database schema and mapped to the OWL ontology using a graphical user interface as shown in Figure 6. After the completion of the mapping process, OAM is able to create a knowledge base in Resource Description Framework (RDF) format which is an application that imposes the needed structural constraints to provide unambiguous methods of expressing semantics (Miller, 1998). The OAM semantic search application was used in developing a search system for historical Lanna kingdom which allows the user to browse and do semantic search.

Figure 6 Mapping classes in ontology with database tables.

To demonstrate the application of Lanna historical ontology, we developed a semantic search system for querying of Lanna historical information. For example, the query can be asked with the following phrase such as the royal monastery temples in Chiang Mai built by which king of Lanna in Mangrai dynasty era. This is a sample of complex queries that can be answered by the system based on a concept-based search. Through the semantic search system, the answer can be retrieved from the knowledge base accordingly as shown in Figure 7.



ชื่อวัด (Temple)	จังหวัด (Province)	สถานะ (Relation Type)	ชื่อกษัตริย์ (King' name)	ปีพุทธศักราชที่สร้างวัด (Buddhist Era)	พุทธศตวรรษ (Buddhist Century)	ยุคในล้านนา (Era)
วัดเชียงมั่น	เชียงใหม่	สร้างโดย	พญามังราย	1839	19	สมัยอาณาจักรล้านนารุ่งเรือง
วัดพระสิงห์วรมหาวิหาร	เชียงใหม่	สร้างโดย	พญาผายู	1889	19	สมัยอาณาจักรล้านนารุ่งเรือง
วัดสวนดอก	เชียงใหม่	สร้างโดย	พญากือนา	1914	20	สมัยอาณาจักรล้านนารุ่งเรือง
วัดเจ็ดยอด (โพธาราม)	เชียงใหม่	สร้างโดย	พญาติโลกราช	1998	20	สมัยอาณาจักรล้านนารุ่งเรือง

Figure 7 Example of the semantic search results.

EXPERIMENTS AND EVALUATION

The experiment is set up to evaluate the proposed ontology to search the Lanna kingdom history about the relationships of the king who built the temple, created or restored the historical site located within its grounds, and the year of the creation. The experimental result is evaluated by 18 designed queries, which is classified into 4 groups of interests. They are as follow: Q1; "The queries related to the relationship between temples and kings" is for searching the name of the king who built a temple or who created or restored the historical sites, Q2; "The queries related to the relationship between temples, kings and year of the event" is for searching the name of the king who built a temple and year it was built, Q3; "The queries related to the relationship between temples, historical site, kings and year of the event" is for searching the name of the king who created or restored a historical site within temple ground and year of the event, and Q4; "The queries to infer the year the temple was built from a list of the historical site of the temple" for the temple that has no year of construction or of the temple's creator can be used to infer the year, as shown in Table 3.

Table 3 The group of queries.

No.	Query
Q1: The queries related to the relationship between temples and kings.	
1	Temples built by king Mangrai.
2	Royal monastery built by king.
3	Local temples in Chiang Mai built by king Tilokaraj.
4	Temples with historical information in king Tilokaraj.
Q2: The queries related to the relationship between temples, kings and year of the event.	
5	Temples built in Mangrai Dynasty from 1084 to 1900 BE.
6	Temples built by king in 20 BC (Buddhist Century).
7	Royal monasteries in Chiang Mai built by king in Mangrai Dynasty.
8	Temples built during Vassal Statehood of Siam by king Kavilot Suriyawong.
9	Temples in Chiang Mai built during Burmese Occupation in 22 BC (Buddhist Century).
10	Temples in Chiang Mai with historical events during Burmese Occupation in 23 BC (Buddhist Century).
Q3: The queries related to the relationship between temples, historical site, kings and year of the event.	
11	Temple historical site built by king in 21 BC (Buddhist Century).
12	Temple historical site built by king in Mangrai Dynasty from 1804 to 1900 BE.
13	Temple historical site built in Mangrai Dynasty by king Chaisongkhram.
14	Chapels built by king in Lanna kingdom.
15	Stupa of Chedi Luang temple in Chiang Mai built and restore by king.

No.	Query
Q4: The queries to inference the year built the temple from a list of the historical site of its.	
16	Don Ton Temple in Nan built through inference from actual year chapel built and restored.
17	Nam Hu Temple in Mae Hongson built through inference from the actual year chapel and pagoda built.
18	TonYang Luang Temple in Chiang Mai built through inference from actual year Scripture hall built and pagoda restored.

The system's evaluation was based on the relevance of the results retrieved by the system. The measurements used for this experimental setting was Precision, Recall, and F-measure. They were used to compute the evaluation of the performance of the semantic search for Lanna kingdom history by using equation (1), (2), and (3) respectively.

$$\text{Precision} = \frac{\text{Number of results retrieved and correctly}}{\text{Total number of results retrieved}} \times 100 \quad (1)$$

$$\text{Recall} = \frac{\text{Number of results retrieved and correctly by expert}}{\text{Total number of results retrieved}} \times 100 \quad (2)$$

$$\text{F-measure} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (3)$$

Precision is the percentage of retrieved results and correct correspondence with the total number of results retrieved.

Recall refers to the percentage of the correct retrieved result correspondence by a domain expert with the total number retrieved.

F-measure is the percentage of the harmonic mean of precision and recall.

The evaluation method is done by comparing the results retrieved to the correct results in the database. In addition, it was evaluated by three history experts. The performance of the semantic search is shown in Table 4.

Table 4 The semantic search performance.

Query	Precision (%)	Recall (%)	F-measure (%)
Q1	100.00	81.81	89.99
Q2	100.00	70.53	82.72
Q3	100.00	91.78	95.71
Q4	100.00	77.78	87.50
Average	**100.00**	**80.47**	**89.18**

Table 4 shows the performance of the Lanna historical ontology based on the 4 groups of queries. For the precision values, all groups have 100%, this is because the precision measured by the data within the database, which normally has no mistakes if correct coding. While the value of recall is confirmed by the historical

experts, which there are three experts in this study. The performance of Q3 is the highest in all three measures. Since its queries related to the king name with the relationships with historical site and range of years, most of experts quite agreed with the searched results, i.e. a high recall value. Similar to Q1, which the queries are related to the king names and temples, has the performance at the second rank.

In contrast to Q2 and Q4, they have the lowest rate of recall 70.53% and 77.78, respectively. This is because queries of Q2 and Q4 are related to year and time period, while different data sources passed through personal accounts or legends down from generation to generation, are probably not agreeable in some points depending on the writer, especially year and time. Thus, the searched results from the data do not match with the data source of experts.

In addition, Q4 is our proposed of using ontology for the year of temple construction inference, in the case of no construction time period of the temple in the documents. By inferring the time period of artefacts or ancient sites related to the temple, we can infer year of temple construction. From the experiment, it shows that using pagodas and chapels gives higher rate of accuracy. It is due to the fact that most pagodas and chapels were built almost at the same time as the temples built. Therefore, using other ancient sites for inference are likely to less accuracy. Moreover, in the case of the temple with no year of construction or temple's creator, Buddhist century (BC) of building the historical site can be used to infer the year and using Buddhist century (BC) is considered to be more accurate by domain experts.

However, our proposed ontology semantic search can perform based on three measures with overall average over 80%. It can also support complex searches by using object property by connecting the relationship of classes according to the structure of the designed ontology which has more flexibility than previous historical search applications.

The Lanna historical ontology from this study can be further used in developing a web-based application that supports Lanna history as depicted in Figure 8. This application has applied the concept of using principle semantic search and analyzed the results from the system created by the OAM program focusing on searches that shows relations of temples, historical sites, kings and time period. The picture displays a sample search of temples constructed by King Mangrai during the Mangrai Dynasty. The search results consist of Chiang Man temple, its historical data, construction data, and image of the temple along with information provided on the right-hand side that is relevant to this temple including a list of temples built in the same era, historical sites, ancient artifacts and location map.

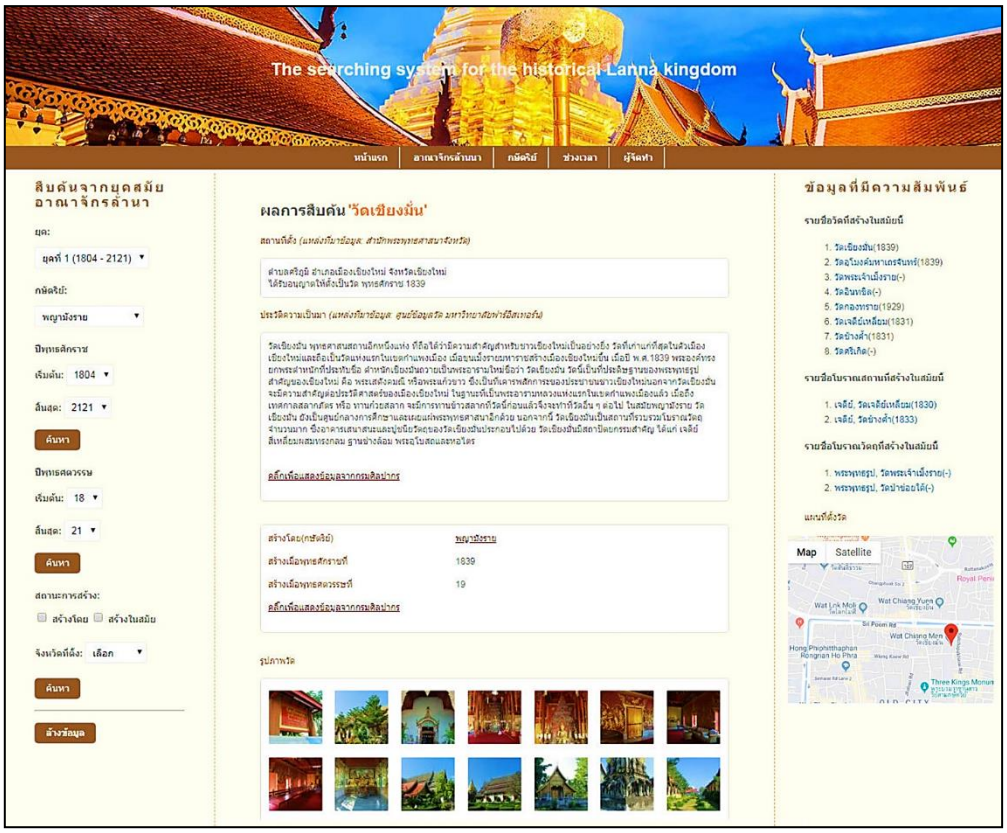


Figure 8 The Web-based application for the Lanna kingdom history.

CONCLUSION

In this paper, we presented a semantic search application for historical concepts search in Lanna Historical Ontology which consists of 8 major classes. The system analyzes the natural language queries and matches them against the database to retrieve historical data from the ontology. This is done by employing semantic web applications capabilities such as ontology annotations and use of inference engine to infer over given facts. The semantic search system shows that the application of ontology technique to show relationship between Lanna King Histories in Buddhist temples improves precision as shown in Table 4. The system has a performance result of 100% precision and 80.47% recall when applying on queries to retrieve historical concepts from the Lanna Kingdom. The system is able to accept user queries and retrieve the answer with a good precision and recall. Furthermore, the previous study of ontology for historical domain to support semantic document retrieval could facilitate and support the retrieval of historical document based on event query from battles and operations in the Vietnam War, which has a similar accuracy with our proposed system (Ramli and Noah, 2016).

However, we found that the data sources of historical Lanna kingdom are from many organizations and data stored from different data sources such as myth, the records of the government departments, or scientific evidence, etc. This may cause the evaluation of some queries from each expert not agreeable. For future work, we will present the information from many sources, including the origin of the source, for the users to compare or find facts before using them. In addition, we will improve the development and extension of our approach to be applied in other areas of historical domains. Moreover, we plan to apply the inference methodology for missing values from other information related such as the name of the king and the year of the ancient artifact construction which may make the information more reliable.

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