Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Ontology Model for Hajj using Ontology Development 101 Methodology

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ARTICLE INFO

Article history:
Received 25 February 2025
Received in revised form 25 July 2025
Accepted 18 August 2025
Available online 25 August 2025

Keywords:
Hajj; ontology development 101; Quran; Islamic domain

ABSTRACT

Hajj and Umrah are fundamental spiritual journeys in Islam, requiring proper knowledge and preparation. However, information related to these rituals is scattered across historical texts, religious scriptures and online sources, making it difficult to access and understand. The challenge of structuring and organizing knowledge is not unique to religious studies but extends to other domains, such as mental health awareness and Islamic thought. With the advancement of technology, particularly artificial intelligence (AI) and ontology-based systems, structured knowledge representation has become increasingly valuable. This study develops a Hajj ontology as a structured knowledge base to systematically organize pilgrimage-related information. The Ontology Development 101 (OD101) methodology was adopted, consisting of specification, integration, conceptualization, implementation and evaluation phases. The integration phase combined elements from Umrah ontology and Qur'an ontology, ensuring a more comprehensive representation of pilgrimage knowledge. The developed ontology was successfully implemented due to the simplicity and flexibility of the methodology. Protégé was used for visualization, while SPARQL queries enabled knowledge retrieval, addressing competency questions and enhancing accessibility. This structured approach demonstrates the potential of ontology-based models to improve understanding and decision-making in religious studies. Beyond Islamic studies, ontology-based frameworks have broader applications. In mental health research, structuring knowledge on psychological well-being, such as stress, anxiety and depression, can support more effective awareness strategies. Similarly, in Islamic thought and AI-driven knowledge systems, ontology models help organize and interpret religious teachings, ensuring alignment with Islamic principles. This study highlights how ontology can bridge the gap between fragmented information sources and structured knowledge representation, offering a foundation for further research in religious studies, mental health awareness, and AI-driven knowledge management.

1. Introduction

Hajj is one of the five Pillars of Islam and is a sacred pilgrimage that each Muslim must accomplish at least once throughout their lives. Hajj is a complex and significant religious pilgrimage with various

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https://doi.org/10.37934/ard.141.1.241256

rituals, rules and historical context. It can be visualized and represented through knowledge graphs. The graphs can be expanded to effectively enhance knowledge discovery. This allows for the application and exploration of various analytical techniques to analyse and visualize the data [1].

Information on the Hajj comes from various sources, including historical texts, guidebooks, religious scriptures, journals, blogs and other media. The information on Hajj can also be accessed through the Qur'an and Hadith. In the Qur'an, information related to Hajj can be accessed through different chapters. It has a chapter, namely the "Hajj," but not all the verses in this chapter discuss the Hajj. Thus, the organization of information related to Hajj is scattered.

A rising number of fields have shown interest in creating and developing an ontology in recent years. An ontology guides the creation of the knowledge graph by defining the types of entities, properties and relations. Relatively few studies, particularly those related to Hajj, were carried out. The knowledge graph about Hajj stored in a repository is important in helping rapid decision-making, especially in matters involving the *hukm* or laws of Hajj [2]. Therefore, this study has utilized the Hajj information to represent an ontology in a structured knowledge graph, making it easier for individuals, scholars and researchers to understand and study the pilgrimage comprehensively.

Beyond religious studies, ontology-based frameworks have significant applications in various domains. The study of Islamic thought and culture is becoming increasingly important due to the global interest in understanding Islam, particularly in the context of political and economic influence. With the rise of artificial intelligence (AI) and other advanced technologies, structuring Islamic knowledge is essential for facilitating effective communication and mutual understanding between nations [3]. However, the integration of new technologies in Islamic studies must be critically examined to ensure alignment with Islamic principles and objectives.

In addition to Islamic studies, ontology-based knowledge representation has been applied in the mental health domain. Mental health issues have been recognized as a significant concern in various industries, including construction, where stress, anxiety and depression impact employee well-being and productivity [4]. Organizing mental health knowledge through ontologies can aid in awareness strategies and provide insights into mitigating workplace-related stress.

An ontology is an explicit specification of a conceptualization [5]. The conceptualization refers to representing a real-world scenario into a set of classes, relations, functions or other objects. Ontology is beneficial for many applications because it can provide an alternative approach to sharing, managing, searching, retrieving and maintaining information [6]. In general, creating an ontology is an engineering task, and there are two major methods for doing so: starting from scratch or employing methods for learning ontologies. Building an ontology from scratch is very difficult and expensive because it will involve domain experts' expertise and ontology engineers' skills [6]. This task needs to be constantly revised and updated by the ontology engineers, especially the new concepts or terms that newly evolve from the basic terms. Consequently, developing ontology from scratch is time-consuming, may cause errors and can be costly. Because of these drawbacks, the term "Ontology Learning" has emerged, which describes an approach for automatically or semi-automatically discovering ontological knowledge from a variety of sources [7,8]. When compared to manual approaches, Ontology Learning substantially speeds up the development of ontologies and can overcome knowledge acquisition challenges.

In the Hajj domain, ontology can be used to define concepts and relations that exist in the domain. It will provide a shared common understanding of certain terms that act as concepts related to Hajj. Ontologies have shown to be very helpful in many fields and are essential to the semantic web [9]. It allows for the integration of data from these diverse sources, creating a more comprehensive and holistic view of the pilgrimage. The ontology was used as a reference knowledge-based; therefore, it must be efficient and reliable in such a way as to best reflect the actual environment concepts.

There are some ontologies that have been developed in the area of Islamic knowledge. Such an example is an ontology from the Book of Purification in Islam [10]. The Purification ontology contains knowledge of the basic ontology for purification is Islam. It is a key to prayer and other rituals such as Hajj or Umrah. Another example is the Salaat ontology [11]. The ontology was embedded in a semantic search engine using API JENA. The implemented search engine can assist a new user in learning about Salaat or Islamic prayer. Keyword-based search was implemented in the search engine to find specific information. It comprises 113 concepts, 85 properties and 40 queries. The methodology called Test-driven Ontology Development (TODE) for ontology development has been used in their study.

Another ontology for Islamic knowledge is the Zakat ontology [12]. It is developed to find the effectiveness of semantic search strategy by considering the Quran, Hadith and Tafsir. The keyword Zakat is used to find all verses related to this keyword. The accuracy was compared with the existing Quran Ontology by Leeds University. An ontology for presenting the Prophet's medicine has been developed to a knowledge base. It is based on secondary Muslim reference i.e Hadith. The ontology uses Ontology Development 101 (OD101) or Noy and McGuiness Methodology [13] in their study. Quran ontology has been developed using Componential analysis of word senses and semantic field theory. The purpose of the ontology is to study the semantic search by enriching queries related to the Qur'an. It produced 19 queries for 6236 records (verses) in the Quran text. The Qur'an ontology has obtained 32 enriched queries.

The Nature domain mentioned in the Qur'an has also been used to develop ontology with the aim of helping semantic search and query on the domain [14]. It uses verses in the Qur'an to generate classes and instances. Query related to the domain has been run to retrieve related verse. An ontology-based on Quranic stories has been developed to study a mapping approach by converting Excel Sheets to OWL using the MappingMaster DSL technique [15]. Results show that the technique produces more individuals, and it is easy to add new classes with their individuals to the ontology automatically from Excel Sheets. The ontology consists of 31 Classes, 35 object properties and 19 data-type properties and 150 individuals.

Quran ontology has been developed using a hybrid approach by first running an automatic extraction using Named Entity Recognition, followed by manual validation of extracted terms [16]. The Qur'an ontology is almost completed ontology, covering a few domains, chapters, verses, pronouns, living things, events, locations and other things. The aim of the ontology is to investigate the semantic-based Qur'anic search engine. It developed a natural language interface that translates Arabic user inquiries into SPARQL queries and then pulls responses from the ontology.

One application of ontology has been developed to model the structure of the Qur'an in order to locate verses that contain the term "Hajj" in Surah Al-Hajj [17]. It has 3 classes, i.e. Juz, Sura and Verse. Yet, the query just displays 8 verses related to the term "Hajj" in Al-Hajj Sura and 30 verses from a whole Qur'an. The ontology does not cover the important concepts of the Hajj.

There is the Qur'an ontology proposed by Arabic Language Computing Research, Quran.com team by the University of Leeds [18]. The ontology has 300 key concepts and 350 relations linking the concepts. The method used to extract concepts is the Named Entity Recognition (NER). However, the ontology is missing in the description of certain concepts and has been extended to improve semantic search [19]. Yet the ontology has placed the Hajj as part of the Calendar Event and does not cover all important concepts of Hajj.

Other than that, a brief of Hajj ontology has been developed for experimenting with Spatio-Temporal database Modelling [20]. It has 39 classes related to the Time of performing Hajj. The modeling is used to assist huge crowds in Hajj events. The aim is to increase the strategies in such a way as to offer assistance and provide quality services. Another ontology of Hajj presents the

hierarchical relationship between the categories that exist in the pilgrimage domain [21]. The ontology doesn't cover the Qur'an that relates to Hajj. Similarly to Hajj, Umrah is also a domain of study [22]. The ontology has been developed to study the semantic-based question-answering system. Pilgrims can post any question about Umrah in natural language format, then the ontology will provide specific answers to the query. The following table 1 shows the discussed Islamic domain.

Table 1
The available ontology in Islamic domain

Domain	Methodology	Reuse	Purpose
Zakat [12]	OD101	Yes	Semantic Search in Quran
Saalat [11]	TOVE	No	Salah Search engine
Book Purification [10]	Proposed methodology	No	Knowledge based
TibbOnto: Prophet Medicine (Tibb Al-Nabawi) [23]	OD101	No	Knowledge Based
Quran Ontology [24]	Componential analysis of word senses and semantic field theory	No	Semantic search engine
Nature domain in Qur'an [14]	Proposed methodology	No	Knowledge based
Quranic stories [15]	3 phases, data collection, ontology modelling, implementation and population	No	Knowledge based
Qur'an Ontology [16]	Hybrid NER	Yes	Semantic Search
Qur'an Ontology [17]	OD101	No	Searching
Quran Ontology [18]	NER	No	Knowledge Based
Hajj Ontology [20]	Not Available	No	Spatial Temporal Database Modelling
Umrah Ontology [22]	Not Available	No	Knowledge Based

Based on the study, it shows that the important concepts in Hajj ontology are not fully discovered, and little research has embedded the reuse ontology. The ontology of Hajj can be explored to find more important concepts with more verses related to Hajj. Besides the Qur'an mentioning the Hajj, it also can be combined with basic knowledge of Hajj and Umrah. Other than that, few studies have established the reuse ontology in its ontology. Thus, this study can embed Umrah ontology and Qur'an Ontology as the reuse ontology in the Hajj ontology. By developing the model of Hajj ontology, more questions about the Hajj or Umrah rituals can be answered, and knowledge-based on more significant concepts of Hajj can be attained.

In terms of the methodology applied, the manual development of ontology uses few methodologies. For example, a methodology namely MENTHONTOLOGY that emphasizes a systematic way of developing ontology by producing either a formal, semi-formal or informal

ontology [25]. The ontology development proposed by Uschold and King employed a middle-out approach in contrast to the classic top-down and bottom-up approach in identifying the important vocabularies in such a domain [26]. OD101 highlights the importance of informal competency questions in determining the scopes of ontology [13]. Most of the methodologies used in ontology development can be defined as an iterative process. It allows the engineers to start with a simple model and refines the ontology every time any changes happen throughout the development [27]. The steps, according to OD101, are to decide the domain scope, consider reusing ontologies, list important terms, recognize the classes and their hierarchy, define the attributes, define the facets of the slots, and generate instances.

During the process of ontology development, specifically the determination of domain and scope, several basic questions will be asked [13,28,29]. These questions refer to the Competency Questions (CQ). The CQ is a list of questions that have been developed for a certain ontology to provide competent answers [28]. It serves as the basis of what content should be included in an ontology.

A content evaluation of an ontology is given by accuracy, completeness, conciseness, adaptability, and clarity [30].

- **Accuracy** can be determined by looking at its definitions, class descriptions, property descriptions, and individual descriptions.
- **Completeness** indicates whether this ontology adequately covers the relevant domain.
- **Conciseness** is the criterion that determines whether an ontology includes items that are unrelated to the area being covered.
- **Adaptability** quantifies the extent to which the ontology predicts applications. An ontology aims to provide the conceptual underpinnings for a variety of anticipated tasks.
- **Clarity** measures how well the ontology conveys the intended meaning of the terms that are defined. Definitions need to be independent and unaffected by the situation.

Besides, it also has been measured by several criterial such as consistency and preciseness [31].

- **Consistency** is referring to the fact that ontology does not contain contradicting data. There is consistency throughout all definitions, and current axioms and definitions do not imply any contradicting knowledge. Here, consistency is defined as both representational consistency and logical consistency.
- **Preciseness** Indicates that ontology has correct definitions and hierarchies and covers fewer undesired models. This means that ontology has a more comprehensive axiomatization.

Other than that, clarity, coherence, extendibility, minimal encoding bias, possibility of multiple inheritances and ease of computation and coherence [32].

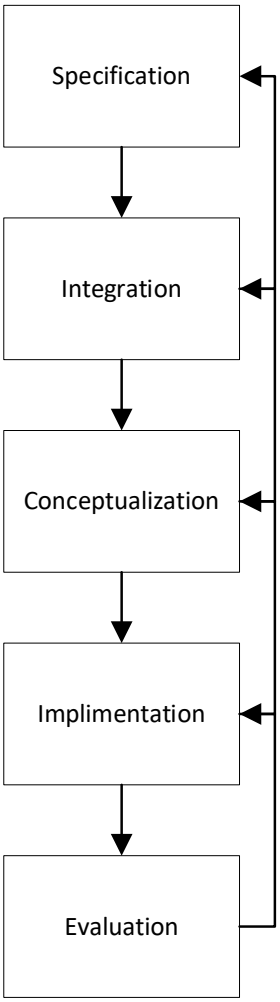
The objectives of this study are as follows to:

i. Model an ontology for Hajj based on important concepts of the Qur'an and basic knowledge of Hajj.
ii. Develop the ontology for Hajj based on methodology 101 methodology.
iii. Evaluate the Hajj ontology using CQ.

2. Methodology

The OD101 [13] has been used to guide the design and developed ontology. The OD101 is chosen because it is simpler, less structured and flexible to be used as a knowledge representation for a domain. In addition, the OD 101 method also addresses the basic and popular of ontology modeling,

thus helping new ontology engineers to model ontologies [27]. The methodology is an iterative process that progressively can be refined whenever changes occur during development. This methodology has 5 stages, namely specification, integration, conceptualization, implementation and evaluation, as shown in Fig. 1.



The 5 stages of the process are as follows:

i. Specification study is an initial stage aims to identify domain scope of the selected domain ontology. It is normally involve developing Competency Question for defining the scope.

ii. Integration stage determine and analyze other ontology that could be embed in the proposed ontology. If exist, then possibly it can be refined and extend from existing sources.

iii. Conceptualization refers to an activity that determine all related classes or concepts, relationship between concepts or other relationship, instances or individual and axioms or rule for a certain ontology.

iv. Implementation stage refer to developing ontology and mostly used software in the development. All classes, relations, instances that defined in previous stages has been encoded here.

v. Evaluation stage is done to test the specification of the system requirements.

Fig. 1. Stages in Ontology development 101 methodology [13]

2.1 SPARQL

A query language and protocol called SPARQL (SPARQL Protocol and RDF Query Language) is used to query and alter data that is stored in Resource Description Framework (RDF) format. The RDF standard is used to describe data as triples, or statements that have a subject, predicate, and object. SPARQL enables users to query and retrieve data from RDF datasets. SPARQL has 4 types of queries, namely SELECT, ASK, CONSTRUCT and DESCRIBE.

2.2 OWL

Web Ontology Language (OWL) is a semantic markup language used to represent and reason about the semantics of information and relationships within a particular domain. OWL is part of the W3C's family of web standards and is designed to enable the creation of ontologies, which are formal

descriptions of knowledge that can be utilized by computer systems to enhance data interoperability and reasoning capabilities.

2.3 Protégé

Protégé is an open-source software platform that provides a user-friendly environment for developing, editing, and managing ontologies. It is widely used in the field of knowledge representation and the development of ontologies for various domains. Protégé supports the OWL using many plugin concepts. Hermit is an example of an OWL reasoner that is available in Protégé [33]. It is used for identifying any inconsistencies in an ontology. Besides, it is also used for classifying individuals and concepts in an ontology. Based on the defined class hierarchy and axioms, it can classify the class membership of individuals.

3. Results and Discussion

3.1 Specification and Integration

At the specification study stage, the activity involve is identifying domain scope and purposes. The domain of Hajj and Umrah encompasses rituals, locations and important tasks related to Hajj. The Umrah is similar to the Hajj but with lesser tasks or steps. As the purpose of the ontology development is to represent the basic understanding of Hajj and Umrah in a structured way, the source is taken from the reliable source as follows: -

i. Verses related to Hajj mention in Qur'an and it was taken from tanzil.net, which is based on the English translated version of Qur'an by Hilali Khan.
ii. *A Handbook of Hajj and Umrah* [34] which provide basic knowledge of Hajj.
iii. A book of *Kursus Asas Haji* https://www.tabunghaji.gov.my/ms/haji/bimbingan/nota-kursus-asas-haji-kah
iv. Website https://www.islamic-relief.org.uk/resources/knowledge-base/five-pillars-of-islam/hajj/

The use of OD101 methodology highlights the importance of informal Competency Questions (CQ) in determining the scopes of ontology. This stage has explored the CQ by identifying the most relevant CQ from books and websites. All questions are based on basic knowledge about Hajj and Umrah. Some questions come from a book based on Malay Language, titled *"Soal Jawab Ibadat Haji, Umrah dan Ziarah," which is* based on Frequent Ask Questions (FAQ) regarding pilgrimage or Hajj and Umra. The book was relevant to be referred to as it is provided by "*Lembaga Tabung Haji*" which is a fund board that handles pilgrimage events every year in Malaysia [35]. There are 45 groups of questions with a total of 379 questions available in the book. It covers the scope of Hajj and Umrah. However, many questions from the book are more likely specific questions about real-life situations, for example, "*How to kiss Hajarul Aswad while performing Tawaf?"*

The relevant questions are manually selected from the book and website. It is based on the rules that questions that are too general or too specific and questions beyond the query capability, i.e., complex, have not been selected. The purpose is to ensure that an answer can only be retrieved by having a basic knowledge of Hajj. For example, questions like "When will the hajj be performed?" and "When should pilgrims perform the Hajj?", both questions will lead to duplicate answers. This kind of question will only select one question. Apart from that, questions like, *"Is it possible to give money to the poor instead of going to the Hajj?", "Are the expenditure of the pilgrimage costs of a*

spouse obliged to be paid by the husband?" and "*Can I smoke when I am in ihram?"* also have been removed because it is a general question that will produce too general answers. Based on the selected question, only 30 questions have been selected as the CQ. The following Table 2 shows the CQ for the Hajj domain.

Table 2
Competency questions for Hajj domain

No. of CQ	Competency questions
1	What is Hajj?
2	What are the benefits of performing Hajj
3	What are concepts related to Hajj?
4	What is the Hukm of performing Hajj and Umrah?
5	What is Wukuf at Arafat?
6	When to do Wukuf?
7	What are prerequisite to perform Hajj?
8	What are the types of Hajj?
9	List what are the requirement to perform Wukuf?
10	When to performed Hajj?
11	What is the definition of Hajj Ifrad?
12	What are the things that need to be completed before doing Tawaf?
13	Where is the Miqat places?
14	Where is the pace Hajj contain restrictions?
15	What are the restrictions in Hajj?
16	What are animals that can be sacrificed?
17	What are Rukn of Hajj"?
18	What are the steps in performing Hajj?
19	What are the steps taken for each of the types of Hajj?
20	What is the verse mentioned about who should perform Hajj?
21	What are the verses mentioned about Ihram?
22	What are the topics of Hajj mention in Qur'an?
23	What are requirements of Ihram?
24	What are the places for each event in the rituals of Hajj?
25	What topics have been discussed about Hajj in Qur'an?
26	How many verses related to Hajj?
27	What are the verses of the Quran that command the call for Hajj?
28	What verse explains the obligation to perform Hajj?
29	What verse explains the Umrah?
30	What verse mention in translation about the type of Hajj?

At the integration stage, this study has considered other ontologies to be embedded in the Hajj ontology. If possible, the proposed ontology can be refined and extended from existing sources. This concept is known as the reusing of existing ontology. Existing ontologies might be compulsory if the system needs to interact with other applications that have already been dedicated to particular ontologies [36]. Based on the literature, there is an ontology that is related to Hajj, which is the Umrah ontology by Sharef [22]. The Umrah ontology has been reused to be integrated with the proposed model of Hajj. It consists of 7 classes and 26 instances. Another ontology for reuse is the Qur'an ontology based on Hakkoum [16]. The ontology covers the important concepts in the Qur'an.

The reuse methodology constitutes the process of reusing existing ontology and constructing a model of the Hajj ontology. The reuse step in the design step has produced two classes to be added to the ontology based on Quran Ontology, which is Allah and Pillars_of_Islam [16]. From the based classes, a few classes have been extended, such as Verse, Living Creation-Human, Living Creation-

Biological Organism-Animal, Event-yearly Event, Period, Location-Geographic Location and *Location-Construction*.

3.2 Conceptualization

The purpose of this stage is to get a list of comprehensive terms for key concepts within the Hajj ontology model. It includes defining key terms that relate to Hajj, rituals, location and entity involved. Output from this stage is a list of concepts, relations and instances that can be defined from the Hajj domain. For the Hajj related to the Qur'an, the list of concepts is generated using the Ontology Learning approach. It is based on an identified pattern based on previous experiments [37]. Other than that, the concepts are based on selected terms from books and websites. Concepts can be classes or entities that can be identified in the Qur'an related to the Hajj domain. Figure 2 shows the main concepts of Hajj.

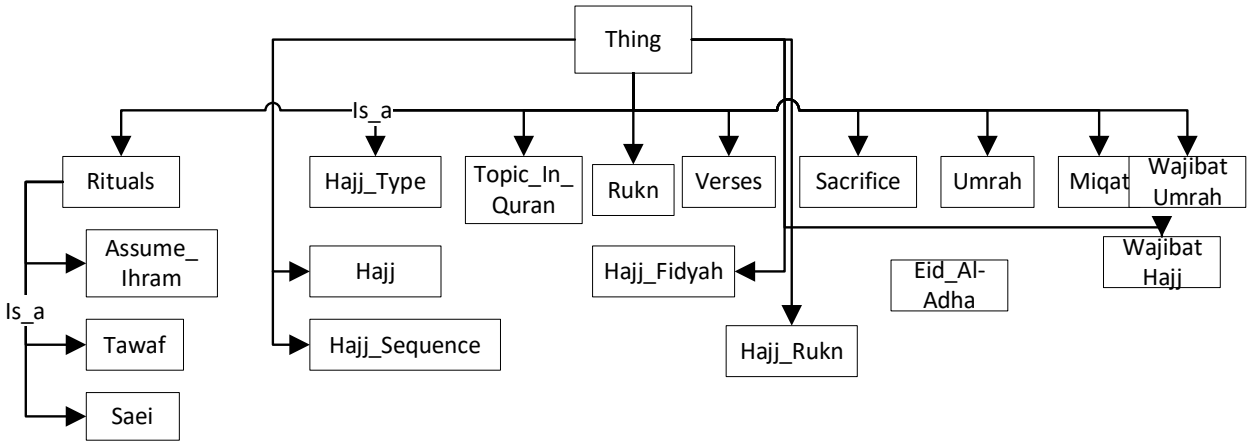


Fig. 2. List of main concepts in Hajj

After the concepts have been identified, the next process is identifying relations between concepts. It is either taxonomy relations or none taxonomy relations. There are several taxonomic relationships used in OD101, such as superclass-of, subclass-of, instance-of and *disjoint class*. Taxonomy *subclass-of* denotes the *"is-a"* relation. It can be defined as if class X is subclass Y if every individual in class X is identical to an individual in class Y. Furthermore, the *superclass-of* relation can be defined as the contrary to the *subclass-of* relation. Meanwhile, the *disjoint class* relation refers to classes whose instances cannot be instances of other classes.

For each concept, it is important to identify the properties of the concept. It can be categorized as either the object property or the data property. The following Table 3 shows examples of the identified properties in Hajj Ontology.

The last activity in this phase is generating instances or individuals. The instances are based on the identified classes. An example of class Verse, it should contain all related verses that mention on Hajj.

Table 3
Example of properties list in Hajj ontology

Property name	Type
hasDefinition	Object property
hasStep,	Object property
hasRules,	Object property
hasRukn	Object property
hasPlace	Object property
hasTime	Object property
hasPerform	Object property
hasRestriction	Object property
hasAyah	Data property
hasMention	Data property

3.3 Implementation and Evaluation

The implementation of Hajj ontology is done using Protégé tool. The tool provides visualization features that allowing to explore and understand the structure of ontologies. All the concepts, relations and instances defined in previous stages has been encoded into the Protégé. Figure 3, shows the main concepts of Qur'an and Hajj.

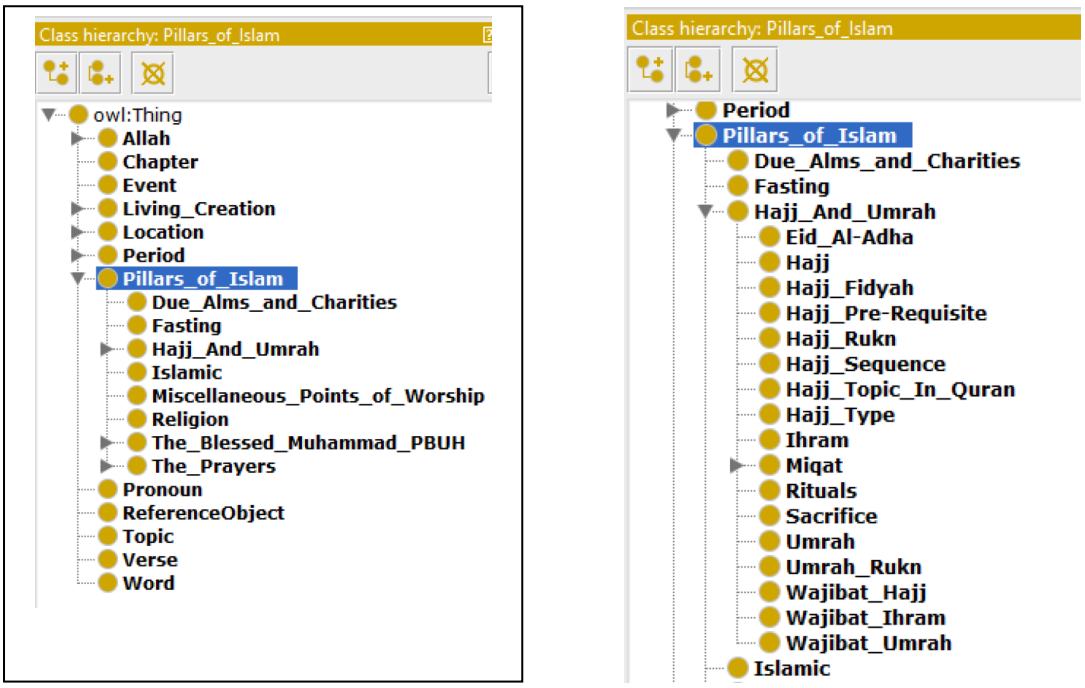


Fig. 3. Main concepts in Quran and Hajj

In evaluation phase, the Hajj ontology has been assessed based only two criteria: consistency, and completeness. Consistency is referring how consistence the Hajj ontology label the data. There are no contradictions in any of the definitions, and they are all consistent. It is done by using the HermiT reasoner through the Protégé program. It is running on class, object properties, and data properties. The HermiT will identify inconsistencies if exists within an ontology.

Completeness is referring to whether this ontology has appropriately covered the Hajj domain [30]. Thus, the Hajj ontology should answer the lists of the CQ as in Table 2. The Hajj ontology should

consider complete if it can answer all the CQ appropriately. The following Table 4 shows some of the output from SPARQL query based on the CQ.

Table 4
Output from SPARQL query based on the CQ

SPARQL query

1. What is Hajj?
SPARQL query:
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>
 	
SELECT ?Hajj_Definition ?Definition
WHERE {
?class rdfs:subclassOf* ab:Hajj.
?Hajj_Definition rdf:type ?class.
?Hajj_Definition ab:hasDefinition ?Definition.
}
Answer
Hajj_Definition | Definition
Hajj_Definition | "Hajj is visiting Baitullah Al-Haram (Kaabah) in Makkah during the montl
Hajj_Definition | "Literally, in Arabic, Hajj means "a resolve", i.e., to resolve to some mat
Hajj_Definition | "Technical term in Shari'ah (Islamic Law)"Hajj is the name of those acts

2. What are the types of Hajj and its definition?
SPARQL query:
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>
 	
SELECT ?Type_of_Hajj ?Definition
WHERE {
?class rdfs:subclassOf* ab:Hajj_Type.
?Type_of_Hajj rdf:type ?class.
?Type_of_Hajj ab:hasDefinition ?Definition.
}
Answer
Type_of_Hajj | Definition
Hajj_al_ifrad | "Hajj al-Ifrad (Arabic: حج الإفراد) involves making one Niyyah for the sole pur
Hajj_at_Tammatu | "Hajj al-Tamattu (Arabic: حج التمتع) involves performing Umrah during the mo
Hajj_Al_Qiran | "Hajj al-Qiran (Arabic: حج القران) involves combining Umrah and Hajj, with on

3. What verse mention of type of Hajj?

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>
SELECT ?Verse_Type_of_Hajj ?Description
WHERE {
        ?class rdfs:subClassOf* ab:Verse.
         ?Verse_Type_of_Hajj rdf:type ?class.
         ?Verse_Type_of_Hajj ab:hasAyah ?Description.
FILTER (regex (?Description, "Tamattu","i")|| regex (?Description, "Qiran","i")||regex (?Description,
"Ifrad","i"))
}
```

Verse_Type_of_Hajj	Description
Qur_2:196	"[2:196] And perform properly (i.e. all the ceremonies according to the

4. What topics of Hajj mention in Quran?

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>

SELECT ?Topic_of_Hajj
            WHERE {
          ?class rdfs:subClassOf *  ab:Topic_of_Hajj.
          ?Topic_of_Hajj rdf:type  ?class.

           }
```

Answer

Topic_of_Hajj
The_Honoured_Kaabah
The_Umrah
Slaughtering_the_Sacrificial_Animals
The_Departure_from_Arafat
The_Rituals
The_Honoured_Macca
Duty_of_Hajj_and_Its_Morals

5. When and where to perform Wuquf

SPARQL query:

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>

SELECT ?Rituals ?Place ?Day ?Time
            WHERE {

          ?class rdfs:subclassOf* ab:Rituals.
           ?Rituals rdf:type ?class.
           ?Rituals ab:hasPlace ?Place.
           ?Rituals ab:hasDay ?Day.
           ?Rituals ab:hasTime ?Time.


           }
```

Answer

Rituals	Place	Day	Time
Wuquf	Arafah	9_Zulhijjah	"the Zawal of 9th of Dhul Hijjah, to the dawn of the 10th of Dhul Hijjah"^^<http://ww

6. What animal can be sacrifice during Hajj that mention in Qur'an?

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ab: <http://www.semanticweb.org/hp/ontologies/2018/5/ontology-Hajj#>

SELECT ?Sacrifice_Animal
        WHERE {
         ?class rdfs:subclassOf* ab:Sacrifice.
         ?Animal rdf:type ?class.
         ?Animal ab:hasAnimal ?Sacrifice_Animal.


 }
```

Answer

Sacrifice_Animal
cattle
camel
Budn
cow
sheep
goat
Oxen

3.4. Discussion

Ontology, in the context of computer science and information systems, plays a crucial role in defining a shared vocabulary, structure, and set of relationships within a particular domain. The development of ontologies is essential for enabling effective data integration, semantic interoperability and machine reasoning. As technologies evolve and the need for better data management grows, advanced tools and engineering practices have emerged to support the development, maintenance and application of ontologies.

One of the key areas where technology has advanced is in the integration of artificial intelligence (AI) and machine learning with ontology engineering. AI algorithms can now assist in the automatic or semi-automatic construction of ontologies by learning patterns from large datasets. This reduces the manual effort involved in designing ontologies, especially for large, complex domains.

AI-powered NLP techniques help in extracting semantic meaning from unstructured text, making it easier to create ontologies that accurately represent the relationships between concepts. NLP algorithms analyse documents, databases or web content to identify key terms and relationships, which can be used to suggest new ontology elements or refine existing ones. With the rise of big data, AI and ML methods are increasingly employed to generate ontologies directly from large, complex datasets. By identifying regularities, patterns and relationships between data points, these technologies help automate the ontology creation process, making it more scalable.

Ontology could benefit many applications especially in the field of semantic Qur'an or knowledge based of Islamic domain. It significantly can be used for retrieving verses related to certain topics in Qur'an. It also can serve as educational purposes for those who are preparing for Hajj or Umrah. The Hajj model of ontology has been developed based on the fact that, important concepts of Hajj has not fully discovered. Besides, few has considered to reuse other ontology in their ontology. Due to this limitation, the first goal was accomplished, which was to create a model of an ontology for the Hajj based on important concepts from the Qur'an and basic knowledge of the Hajj. The constructed model has included important concepts from the Qur'an and the basic knowledge of the Hajj. With

more important concepts has been included in the ontology, it can answer more questions or queries related to Hajj or Umrah.

The second objective has been achieved by developing the ontology for Hajj based on methodology 101 methodology. The process is easier to follow because it is simpler and less formal. The OD101 methodology able to generate 30 CQs in the specification phase. The implementation phase has produced 17 main concepts i.e main concepts mention in Qur'an such as Ihram, Restriction, Rituals and main concepts from books or websites such as Miqat and Hajj Rukn. Object properties as mention in Table 2 also has been generated to relate the classes.

The third objective has been achieved by evaluating the developed ontology using CQ. The CQ has been used to evaluate the completeness of an ontology. The ontology is considered complete if it has addressed every CQ. Aside from that, the HermiT has been used to check for any ontological inconsistencies. It shows that there is no inconsistency exist in the ontology.

The developed Hajj ontology can be used by other applications such as semantic search and data integration or knowledge based in other fields of study. Apart from that, it can be extended for answering more general questions that are not covered by this CQ. Instead of focusing on Hajj, there are several domains in Qur'an that have yet to be thoroughly investigated. Thus, the same methodology applied can also be explored by other domain scope.

Developing the ontology model for Hajj is a challenging effort when dealing with scoping of the domain. A lot of questions are too general to be answer and also beyond the expressive of an ontology language. In terms of text from Qur'an translation, it is not the same with an ordinary document where the translation is based on religious scriptures. Some concepts are hanging without relations between concepts. Meanwhile the organization of verses are scattered. For instance, not all verses in Hajj's Surah explaining about the Hajj, it does contain other topic. Other than that, the Hajj terms are different across country, for example *Jamrah Aqabah* is the same name as *Jamrah Qubra*.

4. Conclusions

Modeling ontology for Hajj domain was successfully been implemented using the OD101. All classes, relation and instances are successfully been encoded in the Protégé application and testing was carried out using the SPARQL query based on the CQ. This model's contribution is the Hajj ontology, which includes more significant concepts related to Umrah and Hajj. Despite that, the ontology acts as a knowledge base that reuse ontology from the ontologies of the Qur'an and the Umrah.

There are some limitations identified in the ontology model of Hajj. The CQ generated might not cover all aspects of Hajj, especially a complex part of Hajj domain. The complex questions need to be answered by domain experts of Qur'an. Another limitation is that the term used might be different. The *same as* function in protégé could be used but function will provide a lot of terms to be instances of classes in the ontology. It will produce a big graph of the ontology that have been developed.

In future, this research will use Qur'an expertise feedback to evaluate other criteria such as preciseness, clarity and conciseness. It also can consider to develop more comprehensive ontology about the Hajj. The visual part of Hajj information also can be embedded in the ontology through other data types such as videos.

Acknowledgement
This project is funded partially by the Centre for Research Excellence, Incubation Management Centre (CREIM), Universiti Sultan Zainal Abidin (UniSZA).

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