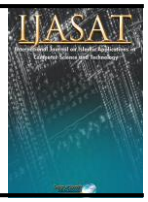

Islamic Ontology Coverage Evaluation

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Abstract
Ontology has become a popular knowledge representation approach extensively utilized in various computational models. Recently, Islamic research has attempted to employ ontology to capture the massive amount of knowledge in the Quran and Hadith. Although many ontologies are produced to cover different aspects of Islamic topics, the production quality and quantity of Islamic resources are still in the early stages compared to other domains. This need boosts the necessity of evaluating the existing ontology toward building a resource that covers Islamic topics more comprehensibly. In this work, the data-driven evaluation method is applied to evaluate the adequacy of the available Quranic Ontologies, namely QuranOntology and Qurany, in covering the topical concepts for one of the Islam pillars, particularly the Hajj domain. The results show that the existing ontologies do not deeply cover Islamic topics. In addition, the QuranOntology concepts coverage represents 1% precision related to Hajj terminology. On the other hand, only 14 out of 160 Hajj keywords are matched with the ontology concepts, representing approximately a recall of 8.75 %. Therefore, there is a strong need to build knowledge resources that enrich the coverage of Islamic topics.

***Keywords*:** Islamic Ontology, Ontology Evaluation, Knowledge Representation, Arabic NLP.

1. Introduction

Ontology plays a vital role in representing a massive amount of information on the web into a semantic form that enables the computer to capture the essential domain knowledge entities and understand the underlying relationships between the data. According to Gruber (1993), ontology can be defined as "the specification of conceptualizations" to share knowledge through precise conceptual models that clearly identify the domain's concepts, attributes, and relations. It has been widely utilized in different areas, such as information retrieval, knowledge extraction, question-answering, and decision-making. Over the last decades, research has contributed to building advanced ontologies in several fields, such as foods, medicine, and genes, in English; in contrast, the Arabic content still needs further development.

The Holy Quran is a fundamental resource that Muslims use to gain religious knowledge. Moreover, over the years, Islamic scholars have endeavored to explain the Quran and clarify its rulings to people through traditional sources such as books of interpretation and jurisprudence. The considerable amount of Islamic content attracted the AI researcher to exploit ontology for improving Quranic research.

Recently studies have contributed to establishing various Islamic ontologies, which could be considered a valuable base for Quranic knowledge. However, the attempt to build a

comprehensive Islamic ontology is still in its early stages. Hence, it is essential to explore the contents of the available ontologies and examine their coverage of Islamic topics. This study will evaluate the current ontologies focusing on the topical coverage toward building Islamic ontology. Moreover, it aims to assess to which extent the current ontology deeply covers Islamic topics. To achieve this goal, we will narrow the scope of the analysis to Islam's pillars, mainly focusing on the Hajj as a case study.

In the following sections, the current ontologies will be reviewed. Then, the evaluation methods will be explored. Next, the conducted experiment to evaluate the ontology will be explained. Finally, the results will be discussed and analyzed.

2. Related Research on Islamic Ontology

Recently, Quranic research has attempted to transform the massive amount of Quranic knowledge into a machine-readable format. Abbas (2009) developed Qurany ontology[1] based on the "Mushaf Al Tajweed" book. It comprises nearly 1181 concepts related to general Quranic topics built as a tree structure in HTML format. In addition, Dukes (2015) developed the QAC corpus[2] for annotating the syntax and morphologic features of the Quranic texts, which is considered a cornerstone knowledge resource for multiple Quran research. Furthermore, he established a QAC ontology of the Quranic concepts containing around 300 manually extracted concepts from Ibn Kathir's interpretation.

Additionally, one of the significant resources for understanding the Quran is the QuraAna corpus[3]introduced by (Sharaf & Atwell, 2012). They created the corpus manually by annotating over 24,000 Quranic pronouns with their related antecedence. The QuraAna is available in SQL format. Moreover, they built QuraAna ontology in OWL format by extracting about 1,050 antecedence concepts and linking them to their related pronouns via different types of relations such as "has-concept", "has-antecedent", and "has-a-segment".

There are several attempts to integrate the Quranic resources into a unified framework. Sherif & Ngonga Ngomo (2015) proposed a semantic resource, called QVOC, for the Quran that represents the structural, morphological, and translation features of verses into RDF ontological format. They combined the annotation features from Tanzil[4] and the QAC corpora to provide a multilingual ontology, mainly in Arabic and English. Also, they presented a translation of some Quranic words into about 42 languages.

Hakkoum & Raghay (2015) developed an ontology for the Quran, named QuranOntology[5], by integrating QVOC, QurAna, and QAC ontologies to represent Quran's morphological and structural concepts, such as chapters, verses, words, and PronounRef. In addition, they link the verses with related topical concepts from Qurany ontology. Moreover, they expanded the ontology with over 175 concepts manually extracted related to different topics, such as locations and Living Creation from Tafser's book. The resulting ontology consists of over 110,838 concrete concepts and is publicly available in RDF format.

Similarly, Alrehaili & Atwell (2018) presented a new annotated corpus for Quran in MySQL database format that combined the essential features from the QAC, Qurany, and QurAna

[1] quranytopics.appspot.com
[2] https://corpus.quran.com
[3] http://textminingthequran.co
[4] https://tanzil.net/
[5] http://quranontology.com/

knowledge resources. The corpus was enriched by several annotation features such as morphological, structural, chronological, and ontological. The ontological feature covers concepts from Qurany ontology. Alqahtani & Atwell (2018) developed a new Quranic ontology for semantic search systems. The ontology was created by integrating the available Qurany, Arabic Quran Corpus (AQC), and QuraAna resources.

On the other hand, various works attempt to expand the coverage of Quran ontologies topics by focusing on specific domains. Ullah Khan et al. (2013) built a domain-specific ontology for animals mentioned in Quran and utilized it to develop a semantic search model for retrieving the related verses. In addition, Al-Yahya et al. (2010) developed an Arabic lexicon model using ontology for time nouns that appeared in Quran. Similarly, Alromima et al. (2016) developed an ontological model for places nouns appear in Quran.

Despite the great effort expended in the Quran field, on the other hand, few works have recently proposed building knowledge sources for Hadith. Soediono (2016) proposed a domain-specific ontology for the medical area. The domain experts constructed the main concepts and relations based on the "Al-Tibb Al-Nabawi" book, which reviewed the prophet's sayings about healing and diseases. The ontology is then used to annotate sixty Hadiths with related concepts resulting in texts with 165 annotation tags in the RDF format.

Another work by Kadhim et al. (2015) tries to build an ontology for one of Islam's pillars, "Alsalah" which means praying. The resulting ontology consists of 15 main concepts and 82 sub-concepts extracted manually from the index of the Alsalah chapter in the Al-Bukhari book. The primary purpose of the ontology is to annotate Hadith and improve the search process semantically.

The current ontologies are investigated deeply based on different criteria in
Table 1

. There is no doubt that these resources contributed to Islamic NLP research; however, most ontologies are not publicly available. In addition, we observe that ontology's concepts can be

	Scope	Concepts #	Concepts scope	Proportion	Source	Development	Format	Availability	languages	validation	Application
Qurany(Abbas, 2009)	Quran	1180	15 abstract topical	All verses	Mushaf Al Tajweed book	manual	Html	Y	Ar-Eng	Scholarly book	Search
(Al-Yahya et al., 2010)	Quran	69	18 Time	Time words	Time Vocabulary in the Holy Quran book	manually	OWL	Y	AR	Expert	Create lexicon
QAC(Dukes, 2015)	Quran	300	12 abstract topical	some verses	Ibn Kathir's interpretation	manual	Html	Y	Ar-Eng	N/A	Search
QVOC (Sherif & Ngonga Ngomo, 2015)	Quran	N/A	4 structural	All Verses	Tanzil and QAC corpus	semi-automated	RDF	Y	42 Lang.	N/A	N/A
QuranOntology(Hakkoum & Raghay, 2015)	Quran	110,838	14 Abstract	All Verses	Tanzil, QVOC, QurAna, QAC ontology	manually	RDF	Y	AR	N/A	Search
(Alromima et al., 2016)	Quran	110	11 abstract places	places words	linguistic study and QAC ontology	manually	OWL	N	AR	Expert	Create lexicon
(Zouaoui & Rezeg, 2021)	Quran	50000	29 syntax	All	Arabic syntax website	semi-automated	OWL	N	AR	Expert	Search
(Soediono, 2016)	Hadith	165	medical	60 Hadith	Al-Tibb Al-Nabawi and Al-Bukhari books	manually	RDF	N	AR	Expert	Search
(Kadhim et al., 2015)	Hadith	97	15 Alsalah	Alsalah chapter	Al Bukhari book	manually	Html	N	AR	N/A	Search

divided into three types structural, morphological, and topical. Several works have focused on

representing the structural relations between Quran parts, such as verses and chapters. In addition, the morphological specification of the Quran segments is explored. Moreover, few ontologies cover topical abstract concepts, such as the pillars of Islam, worship, ethics, times, and historical stories, for all Quran verses, and only three are available.

The most diverse ontology regarding the topics, reaching up to 15, are Qurany ontology (Abbas, 2009) and QuranOntology (Hakkoum & Raghay, 2015). In addition, among the available, the QuranOntology ontology integrates the most widely used ontologies, namely Qurany, QurAna, QAC, and QOVC, and it can be considered a basis for our evaluation.

3. Ontology Evaluation

Ullah Khan et al. (2013) indicate that the ontology development process is an iterative process that is never completed. The evaluation process is a crucial step in refining and improving ontology. Brank et al. (2005) state that it is difficult to evaluate the whole ontology once due to its complex structure; consequently, the process of ontology evaluation should take place at different levels, such as lexical, hierarchy, concepts, and data. The ontology evaluation approaches can be classified into five main types task-based, golden-standard-based, data-driven, criteria-driven, and human evaluation (Brank et al., 2005; Raad & Cruz, 2015). Each method addressed different criteria to be met throughout the evaluation process, such as clarity, consistency, and completeness (Hlomani & Stacey, 2014; Raad & Cruz, 2015).

Table 1: Comparison of the Islamic Ontologies

This paper studies the coverage of existing Islamic ontologies toward Hajj domain knowledge. Therefore, the appropriate approach for this purpose is the data-driven evaluation method. This

	Scope	Concepts #	Concepts scope	Proportion	Source	Development	Format	Availability	languages	validation	Application
Qurany(Abbas, 2009)	Quran	1180	15 abstract topical	All verses	Mushaf Al Tajweed book	manual	Html	Y	Ar-Eng	Scholarly book	Search
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(Zouaoui & Rezeg, 2021)	Quran	50000	29 syntax	All	Arabic syntax website	semi-automated	OWL	N	AR	Expert	Search
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(Kadhim et al., 2015)	Hadith	97	15 Alsalah	Alsalah chapter	Al Bukhari book	manually	Html	N	AR	N/A	Search

method helps assess the ontology's coverage by comparing it against existing data or corpus

that significantly covers the domain. The process of comparing more than one ontology against the corpus can be conducted by counting the overlap concepts between the ontology and the targeted data. The data-driven method is first introduced by (Brewster et al., 2004). The authors proposed an evaluation method to study the coverage by measuring the overlap between ontology and terms related to a specific domain. The approach first laid on extracting domain-specific keywords from the domain corpus using Latent Semantic Analysis and clustering techniques. Then, the extracted terms are expanded utilizing WordNet and mapped to their related ontology concepts.

4. Experiment

This section will present the conducted experiment to evaluate the coverage of the current available Islamic ontology to promote its usability in pillars of Islam domain knowledge, particularly in the Hajj field. We adopted the data-driven approach proposed by (Brewster et al., 2004) that depends on comparing the targeted ontology against data from the domain-specific corpus. The experiment is based on two main phases: preparing the datasets and the evaluation process, as shown in Figure 1. The following subsection will outline the methodology utilized to undertake this experiment.

4.1 Datasets

As discussed earlier, the data-driven approach is based on two primary resources the target ontology and the domain-specific dataset. In this work, QuranOntology (Hakkoum & Raghay, 2015) will be used as a baseline ontology for evaluation since it is available and integrates other important ontologies, particularly QVOC, QurAna, Qurana, and QAC ontology. The ontology consists of different types of concepts, namely structural, morphological, and topical. The structural concepts represent the organizational features of the Quran into chapters and verses, while the morphological concepts refer to some word features such as POS tag, word lemma, and pronoun reference. On the other hand, the domain dataset in this experiment is based on the “Mua'jam Alfadh Al-Hajj" book (Dawoad, 2020). It explains the Hajj's unique terms mentioned in Quran, Hadith, or Fekeh's book. The terms represent the name of places, times, and special duties related to Hajj.

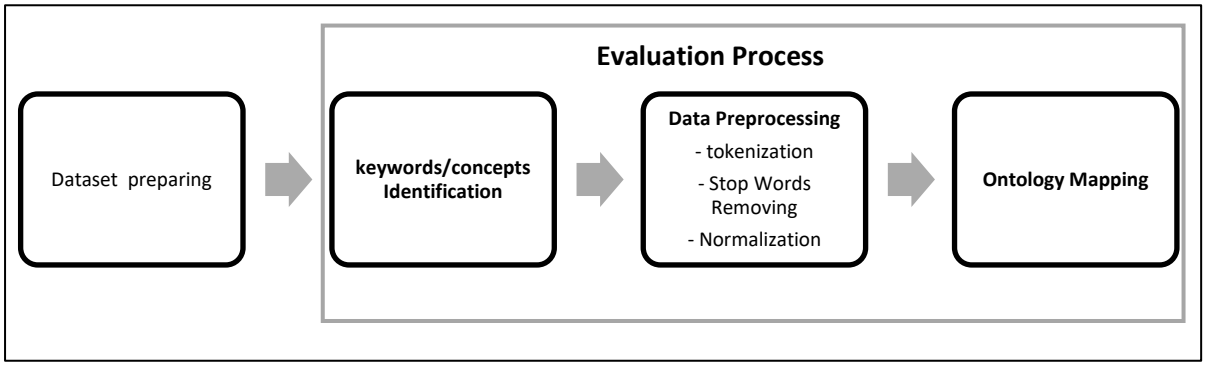


Figure 1: The Methodology Used for Conducting the Experiment

Table 2 illustrates the statistical distribution of the different types of concepts in the QuranOntology. Since this work focuses on the ontology's topical coverage, we exclude the structural and morphological concepts. The remaining concepts are about 1481, covering various Quranic topicals related to different aspects.

On the other hand, the domain dataset in this experiment is based on the "Mua'jam Alfadh Al-Hajj" book (Dawoad, 2020). It explains the Hajj's unique terms mentioned in Quran,

Hadith, or Fekeh's book. The terms represent the name of places, times, and special duties related to Hajj.

Table 2: The statistics of the different types of concepts (Hakkoum & Raghay, 2015)

Concepts type	Number of the instance
Chapter	114
Verse	6236
Word	77430
PronounRefrence	24674
ReferenceObject	1028
Topical	1481

4.2 Ontology evaluation process

The evaluation process comprises three phases: keywords/concepts identification, text preprocessing, and ontology mapping.

4.2.1 Keywords/Concepts Identification

The first step in the evaluation process is to extract the essential terms from the existing resources. In the rest of this paper, we unified the naming of extracted terms according to their original dataset to be concepts and keywords. The concept terms are extracted from the target ontology, while keywords are extracted from the domain corpus. As mentioned earlier, the QuranOntology comprises different types of concepts, and we focus on topical concepts. The extracting process of the topical terms is done using the SPARQL queries via Apache Jena Fuseki. Figure 2 illustrates an example of the queries. The results have been saved in a list of about 1481 concepts.

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
SELECT * WHERE {
?entity rdf:type ?type.
OPTIONAL{?entity rdfs:label ?label }
FILTER langMatches( lang(?label), "ar" )
FILTER (REGEX(STR(?type), "Topic", "i")). }
```

Figure 2: SPARQL query for extracting the topical concepts

On the other hand, the domain-specific keywords have been extracted from the "Mua'jam Alfadh Al-Hajj" book. In the experiment, we created a list of keywords related to Hajj by focusing on the headings only because it represents the primary terminology.

4.2.2 Data Preprocessing

This phase is essential in preparing the data for the comparison stage. The output of this phase is two lists of terms, List-1 and List-2. The first list consists of the topical concepts from QuranOntology. In contrast, the second list consists of the Hajj keywords extracted in the previous phase. The following preprocessing steps are applied:

A. Tokenization

This phase depends on splitting the texts into tokens by whitespaces. In fact, due to the nature of the domain-specific concepts, the extracted terms might be single or multiple words that refer to one terminology in the domain. Hence, we treated the multiple words concepts as one token in this experiment.

B. Stop Words Removing

Stop words are the most frequently repeated words that do not provide any beneficial information, such as " في , على ,من". The Arabic NLTK stop words list is used in this step. Removing the stop words allows focusing on the most essential words in the multiword concepts.

C. Normalization

This procedure is essential for producing a unified word form. It consists of the following steps :

- Strip the diacritics to produce an un-vowelized form of the word, such as " الْكَعْبَةُ " to "الكعبة".
- Remove the prefix"ال " from the beginning of words: e.g.,"الكعبة " will be "كعبة "

4.2.3 Ontology Mapping

The final step in the evaluation is mapping the Hajj terms from List 2 to the matched concepts from List 1. This step is essential to measure the overlap between the two lists. We applied two matching methods, exact and partial match. The first method returns only the results that match the list's terms exactly, while the second method returns results that partially match any words in the terms to retrieve all candidate concepts from the ontology.

5. Results

After excluding the structural and morphological concepts from the QuranOntology, we end with a total of 1481 topical concepts. As mentioned earlier, QuranOntology integrates different ontologies besides their new topical extracted concepts from the Quran interpretation book. After analyzing the extracted concepts, we observed that the number of new topical concepts added by the authors is roughly 310, and the remaining are integrated initially from the Qurany ontology. This experiment counts the number of matches between concepts and Hajj keywords to measure the coverage. Furthermore, the matching process is conducted separately for each sub-ontologies to gain detailed coverage information.

We apply two ontology evaluation measures, precision and recall, to compare the ontology against a list of domain-specific keywords. Precision is defined as the number of correctly matched over the total concepts in the ontology, while recall is the number of correctly matched over the knowledge that should be covered (Hlomani & Stacey, 2014). Given a list of keywords K representing the domain, the set C of the ontological concepts, and a set $K_{matching}$ representing the matching concepts with the domain keywords, the precision and recall are based on the following formula defined in (Rospocher et al., 2012)

$$\text{Precision}=\frac{K_{\text{matching}}}{\text{C}} \quad (1)$$

$$\text{Recall}=\frac{K_{\text{matching}}}{K} \quad (2)$$

According to the evaluation results, it is clear that the QuranOntology does not adequately represent the Hajj terminology; the total topical concepts that correctly represented Hajj keywords represent 1% precision. This figure comprises 15 matched concepts that can be

divided into 0.29% unique concepts from Qurany ontology and about 0.29% newly added concepts in QuranOntology, while the rest is considered as overlap concepts between the sub-ontologies, forming 0.43%.

Moreover, as shown in Table 3, only about 3.23 % of the new topical concepts added by Hakkoum and Raghay match Hajj keywords, while 0.85% of the Qurany ontology covers the Hajj domain. On the other hand, only 14 out of 160 Hajj keywords are founded in the existing ontology, representing nearly a recall of 8.75 %.

Table 3: The Experiment Results

	New added concepts in QuranOntology	Qurany concepts	All distinct topical concepts in QuranOntology
Concepts	310	1181	1481
The number of matched	10	10	14
Precision	3.23%	0.85%	1 %
Recall	6.25%	6.25%	8.75 %
Example of the extracted concepts	'صفا', 'مروة', 'حج', 'عرفات'، 'عمرة'، 'مشعر حرام', 'مسجد حرام' ,'كعبة مشرفة' , 'مكة المكرمة', 'بيت حرام'	'الحج' ,'مناسك' ,'نحر', 'قصر صلاة','إفاضة ' , 'مسجد حرام', 'كعبة مشرفة', 'مكة مكرمة', 'عمرة' ، 'بيت حرام'	

After applying the partial match, we found that some words in the Hajj keywords List-2 partially matched the ontology's concepts in List-1. For example, the terms "مكة" and "كعبة", which refer to Mecca city and Kaabah, from List-1, were matched partially with the terms " مكة المكرمة" and "كعبة مشرفة" in List-2, respectively. Moreover, we found that approximately five general abstract concepts are partially related to the 20 Hajj keywords. To illustrate, the abstract concept "جبل" meaning mountain, is related to the keyword "جبل الرحمه" meaning " Mercy Mountain" partially, which is considered one of the primary locations in Hajj.

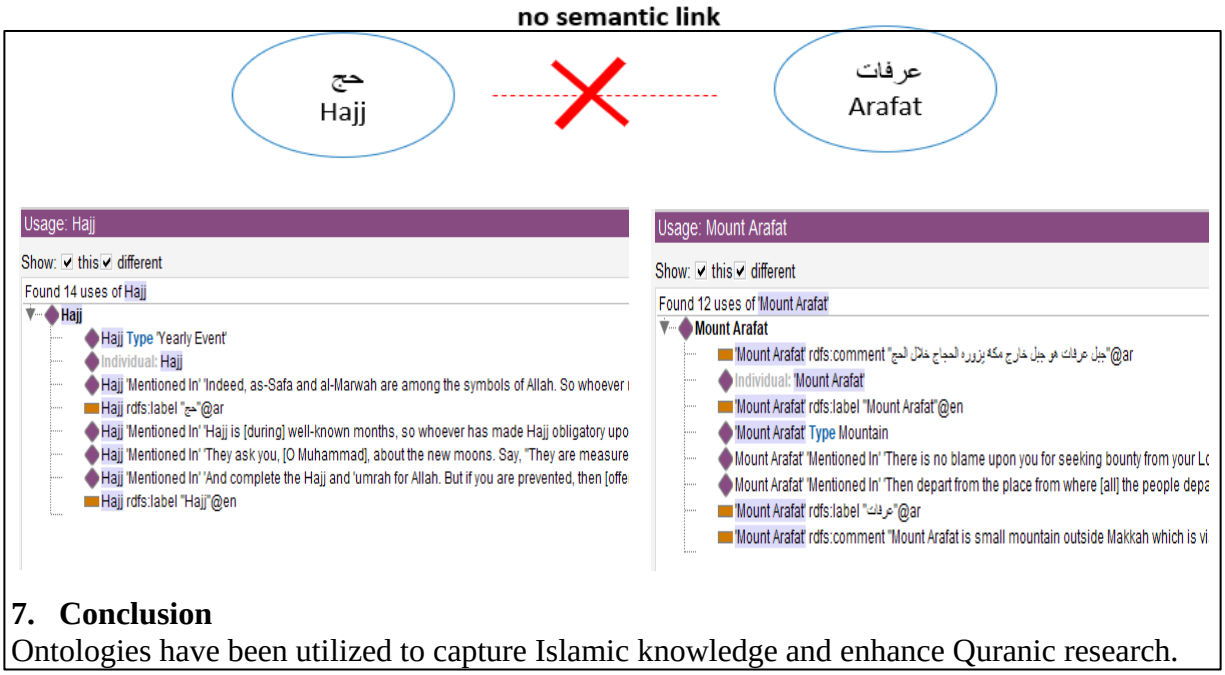
6. Discussion and analysis

The QuranOntology is mainly constructed by integrating existing Quran ontologies that focus on morphological and structural concepts, which could reflect the small coverage percentage of the topical concepts. This result indicates an urgent need to fill the significant concepts gap to help produce a more comprehensive Islamic knowledge resource. Additionally, most of the QuranOntology topical concepts are related to the name of people, animals, and locations that were explicitly mentioned in the Quran and extracted from interpretation books. There is still a shortage of concepts implicitly mentioned in the Quran but explained in the Hadith of Fekkh books, such as the Hajj Timing “ مواقيت الحج” concept.

On the other hand, we found that most of the extracted topical concepts can be considered abstract concepts for different domains linked to their verses. However, there is no depth taxonomy for the targeting domain. For example, the Hajj concept exists as an abstract concept in the QuranOntology related to all verses containing the keyword Hajj. Similarly, "عرفات" Arafat exists under another abstract concept, but there is no semantic link between these

concepts. Figure 3 demonstrates all the relations linked to the instances "Hajj" and "Arafat" in the QuranOntology and shows that they disconnected.

Furthermore, we observe that the ontology contains general concepts such as Hajj, valley, and mountain that partially match the Hajj keywords and could be used as a base for new sub-concepts.



7. Conclusion

Ontologies have been utilized to capture Islamic knowledge and enhance Quranic research.

Figure 3: An Example of the concepts "Hajj" and "Arafat" from QuranOntology

The evaluation process is a crucial step for building a comprehensive Islamic ontology. This paper analyzes the existing ontology to study its limitation regarding Hajj coverage. In addition, the data-driven evaluation method was applied based on QuranOntology as the target ontology and the Hajj domain data. The results show a severe deficiency in the coverage of Islamic topics, which reaches a precision of 1 % in the case of the Hajj domain and most of them are considered abstract concepts. In the future, we will consider building Islamic knowledge resource that covers pillars of Islam topics more comprehensively, which will contribute to Islamic NLP research.

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