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A Study of Ontology Engineering in Malay Unstructured Document Using Entity Relationship Model

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Abstract: The existence of the semantic web has motivated studies in information retrieval and ontology-based knowledge representation. Malay-language ontology engineering is not very encouraging due to Malay language technology has limitation in Natural Language Processing. Furthermore, Malay language is classified as an under-resource language. Therefore, appropriate technique is needed to be applied in Malay-ontology engineering. Thus, the objective of this paper is to find the best approach in generating Malay-ontology. In this study we have develop MyOntologyGen prototype to create automatically Malay-ontology using natural language processing method and apply entity relationship model as a conceptual based to develop MySQL database. The evaluation strategy is to test the accuracy of ontology component against gold standard and model evaluation metrics. The result of average precision in taxonomy relationship between concept is 79% and non-taxonomy relationship is 63%. Hence, it shows that ontology component detection depends on the accuracy of word group detection in early word labelling task.

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Keywords: Ontology Engineering, Conceptual Data Modeling, Entity Relationship Model, Natural Language Processing

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1. Introduction

Study in information retrieval and ontology based knowledge representation has gained interest in the wake of the existence of semantic web technology. The semantic web is to bring in unstructured internet data, machine-readable by using ontology [1]. Although ontology is the philosophical study of being, in information science, ontology has become an automated semantic which was developed by the artificial intelligence community [2]. Ontology engineering is complex, timely and more effort is needed in the development process [3,4]. Most of the studies described ontology engineering ~~is~~ as a complex field that uses natural language processing method, and applies machine learning and knowledge representation [5,6,7,8]. Moreover, in the ontological engineering field, the artificial intelligence community has been exploring new approaches and techniques to construct new ontology engineering in aiming to reduce time and effort [9].

Malay-language ontology engineering is not as progressive compared to English due to knowledge acquisition bottleneck issue [9]. Study in Malay language technologies has a limitation in Natural Language

Processing mostly in Part-of-Speech Tagging, Stemming, Noun Phrase Identification and Syntactic Analysis due to limited Malay language resources [10].

There are a small number of researches related to Malay-language ontology which focus on developing a conceptual model using graphical representation and constructing the ontology using Protégé [5]. Another study has developed ontology learning from Malay documents using unsupervised conceptual clustering approach [10]. Apart from that, [6] has developed MalayIK-Ontology by identifying, organizing and structuring the documents into interrogative structured form in understanding the group of words which they refer to ‘deep-level understanding’. However, the Malay digital resources that are focusing on ontology engineering tools are limited since Malay language is classified as an under-resource language. Therefore, appropriate approach and technique are needed to be applied in Malay-ontology engineering. With regard to data model, most of the studies are using Entity Relationship (ER) Model [15, 16, 17 18]. Other than that, some of the studies had explored graph databases, particularly Neo4j, to store the ontology component [19, 20] and Object Relational Mapping (ORM-ML) that uses XML schema.

Thus, the goal of this paper is to find the best approach to automatically generate Malay-ontology. This paper presents a conceptual data model and Malay-ontology creation process by using natural processing language which adopts the combination of [7] and [8] methods. Therefore, the proposed approach is evaluated to discover the accuracy of the generated Malay-ontology.

2. Methodology

In this study, we propose a conceptual Entity Relationship Model for Malay-ontology engineering as a high-level description of information needed for fundamental design of a database that stores ontology components. Apart from that, we also propose the ontology development process that applies natural processing language with Malay-language technology. We have developed the MyOntologyGen System as a prototype to perform the Malay-ontology creation automatically based on the proposed conceptual data model and ontology development process.

2.1 Ontology Conceptual Model

Conceptual data model, such as Entity Relationship, is to describe the structure of a database as an abstraction in understanding the data in a system [11]. This conceptual data model provides a better understanding and comprehensibility of the ontology content [2]. Hence, [12] has identified that conceptual data modeling as the most practical technique to further comprehend data requirements in system organization.

There are a number of components required in order to design conceptual data modeling for ontology engineering. According to [15] and [16], the components involved in conceptual entity relationship of ontology engineering are as below: -

- Concept: Entity or object exist.
- Attribute: feature regarded as a characteristic of concept or attribute that describes the relationship identifier between concepts.
- Taxonomy relationship: hierarchy relations between concepts.
- Non-Taxonomy relationship: non-hierarchy relation between concepts.

Based on these components, we have designed the conceptual entity relational data modeling of ontology engineering as shown in Fig. 1.

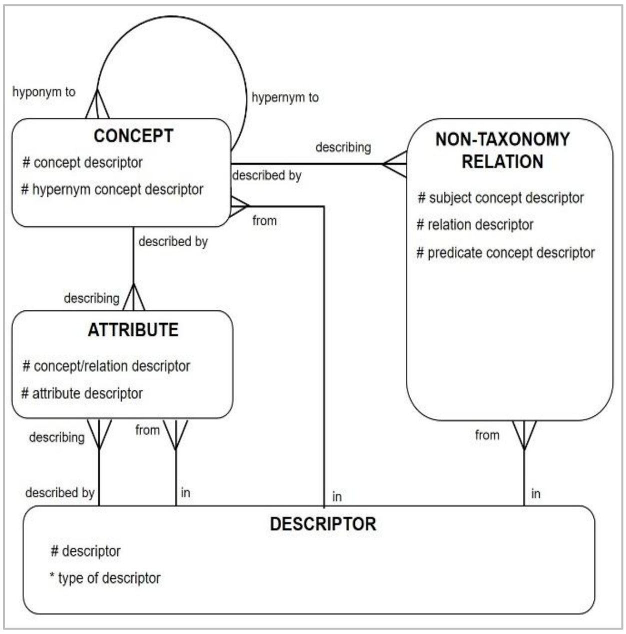

Fig. 1 - Conceptual Entity Relationship Diagram

Fig. 1 has shown that there are four main entities in the conceptual entity relationship of ontology engineering. Description for each entity is as below.

- CONCEPT: Store data that represent things or entities within a domain.
- ATTRIBUTE: Store features, aspects or parts that relate to concept or attribute.
- NON-TAXONOMY: Store non-hierarchy relationship between concepts.
- DESCRIPTOR: To describe or identify attribute, concept and relationship between concepts.

There are three main basic components in the entity relationship diagrams which are entity, attribute, and relationship including modality and cardinality. Relationships between entities are described below.

- Each concept may be hypernym to one or more other concepts.
- Each concept must be a hyponym to one and only one other concept.

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- Each concept may be described by one or more attributes.
- Each attribute may be describing one or more concepts.
- Each non-taxonomy relation may be described by one or more attributes.
- Each attribute may be describing one or more non-taxonomy relationship identifiers.
- Each pair of subject concept and predicate / descriptor / complementary must be described by one and only one non-taxonomy identifier.
- Each non-taxonomy relationship identifier may be describing one or more subject concepts.
- Each subject concept may be described by one or more non-taxonomy relationship identifiers.
- All concept and attribute descriptors, and relationship descriptor identifier must be referred to descriptors in the document.

Based on this conceptual data model, we have developed the database schema as stated by [13] in database development activity. To develop the database, we start with a conceptual data model, then construct it into a logical data model and finally develop the physical data model for data storage in MySQL database.

2.2 Ontology Development Approach

The MyOntologyGen prototype is to develop Malay-ontology automatically from unstructured text document by using natural language processing. The extracted knowledge components and semantic relations are then stored in the MySQL database. Fig. 2 describes the ontology development process.

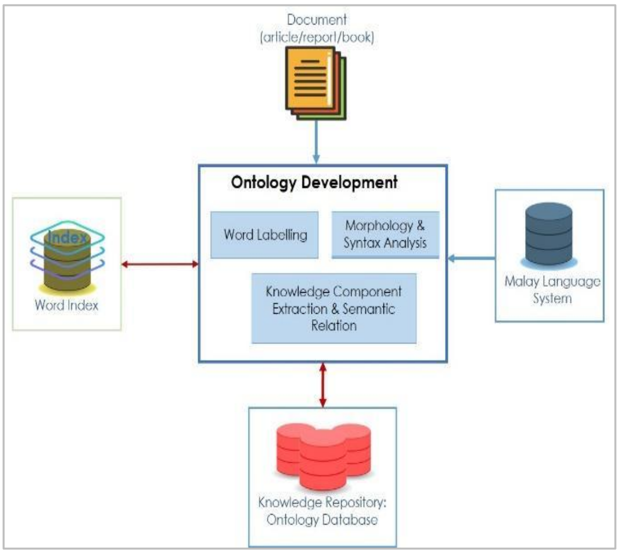

Fig. 2 - Ontology Development Process

There are four main activities involved in the Malay-ontology development process. The activities are (i) text document extraction, (ii) text process and analysis by applying natural processing language, (iii) group of word labeling, (iv) morphology and syntax analysis for taxonomy creation, non-taxonomy identification and finally store extracted knowledge in ontology database.

2.3 Malay Language System (Sistem Bahasa Melayu)

The Malay Language System is a Malay lexicon that consists of 24,874 lemmas, group of words and 71 affixes. The Malay Language System plays a vital role in developing Malay-ontology, particularly in analyzing and identifying morphology and syntax [22]. In this study, we are using components and rules in the Malay Language System to label the group of words and identify their relationships with other words. These components and rules are referred to, during the group of word labeling process, and concept and attribute extraction to form a relationship. The Malay language components and rules are then stored in a MySQL database. The example of data schema on the components and rules for Malay Dictionary Format is as shown in Table 1, Derivative Nouns Format in Table 2, Other Group of Words Format (Kata Ganda, Kata Majmuk, Kata Luar Biasa, Kata Pandu, Kata Henti, Kata Ganti Nama, Kata Penjodoh Bilangan, Kata Bantu dan Kata Penguat) in Table 3 and Taxonomy Rules Format in Table 4.

Table 1 – Malay Dictionary Format

Field Name	Type	Format	Description
Perkataan	*Aksara*	*C30*	*Kata akar*
Golongan_kata	*Numerik*	*N2*	*Kod golongan kata perkataan*

Table 2 - Derivative Noun Format

Field Name	Type	Format	Description
Imbuhan	*Aksara*	*C15*	*Imbuhan*
Jenis	*Numerik*	*N1*	*Kod jenis imbuhan*
Golongan_kata	*Numerik*	*N2*	*Kod golongan kata perkataan yang mempunyai imbuhan ini*

Table 3 - Other Group of Words Format

Field Name	Type	Format	Description
Perkataan	*Aksara*	*C30*	*Perkataan*
Golongan_kata	*Numerik*	*N2*	*Kod golongan kata perkataan*

Table 4 - Taxonomy Rules Format

Field Name	Type	Format	Description
Perkataan	*Aksara*	*C30*	*Perkataan yang menjadi peraturan hukum taksonomi*
Jenis_hubungan	*Numerik*	*N1*	*Kod jenis hubungan sama ada hipernim atau hiponim*

2.4 Text Document Process and Analysis

The unstructured Malay text documents are collected from various resources gathered in a specific domain. Each document is split into sentences, then divided into words for tokenization. Next, a text preprocessing task is performed for text normalization such as lower case, symbol, punctuation and stop word removal. However, comma punctuation is not to be removed since it might be giving a different meaning to a sentence such as a list, coordinating conjunction and compound sentence.

2.5 Group of Word Labeling

Word labeling task is to give context or meaning to the word sequence in a sentence. Morphology analysis is performed to obtain the meaning of every word. Malay morphology structure is complex and needs more effort to label the group of words since Malay Language has tremendous derivative words than English structure [14]. Therefore, an appropriate technique is needed to be applied in the morphology analysis process as below.

- Identify the group of words from Malay Language System rules (noun, verb, adverb and adjective).
- Identify the syntax relationship between sequence of words based on the identified class.
- Plural descriptor for syntax relationship.
- Single descriptor for non-syntax relationship.

2.6 Concept Extraction and Taxonomy Relationship Creation

Ontology concept extraction is carried out by identifying noun words in a sentence. Then, the identified noun is labeled as a concept and finally stored in an ontology database as a component. The concept that has a taxonomy relationship between them is extracted by taxonomy rules (such as hypernym, hyponym) or complex group of words. The identified concept that is extracted by a complex group of words such as 'guru sekolah' will produce a taxonomy relationship as 'guru' - 'guru sekolah'. Besides that, some of word that describe classification of subject, for example 'perabot terdiri daripada kerusi, meja dan almari' can create a taxonomy relationship as 'perabot' - 'kerusi', 'meja' and 'almari'. In this case, 'perabot' is a hypernym to 'kerusi' and 'kerusi' is a hyponym to 'perabot'.

2.7 Attribute Relationship to a Concept Extraction

In this task, a phrase that consists of complementary element words or descriptive words is identified as an attribute relationship. Add to that, an attribute also can be detected by attribute relationship to a concept with word classification as noun, verb, adverb and conjunction word. For example, 'kucing itu mempunyai bulu yang cantik, ekor yang panjang dan boleh melompat tinggi'. List of attributes that is extracted for 'kucing' are 'bulu cantik', 'ekor panjang' and 'lompat tinggi'.

2.8 Non-Taxonomy Relationship

The Non-taxonomy relationship can be identified in a phrase as Noun Phrase (NP) + Verb Phrase (VP) + Noun Phrase (NP) which consist of verbs. For example, 'Ali(NP) menendang(VP) bola(VP)'. The non-taxonomy relationship between 'Ali' and 'bola' is associated by non-taxonomy relationship identifier (verb) 'menendang'. Moreover, non-taxonomy relationships also can be found in compound sentences (NP+VP, VP and VP+NP) with verb phrases that consist of comma punctuation and conjunction words (example: 'dan' and 'serta'). For example, 'Polis mengejar, menembak dan menangkap perompak itu', the verb of 'mengejar', 'menembak', and 'menangkap' are the associate of non-taxonomy relationship between 'polis' and 'perompak'.

3. Evaluation and Results

The evaluation was done to test the accuracy of ontology components that were produced by MyOntologyGen against the gold standard. Our gold standard is the evaluation performed by two ontology experts in extracting ontology components manually. Both of them manually extracted, labeled and identified the taxonomy and non-taxonomy relationship. All the extracted components were then compared with the ontology that was produced by MyOntologyGen.

3.1 Data Set

In this study, we have sampled ten documents from three different online news sites, which focus on the crime domain. Dataset used for this experiment are collected from Berita Harian, Utusan Malaysia and BERNAMA. Statistics of the data set are shown in Table 5.

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Table 5 – Data Set Statistic

Document	Source	Number of sentence	Number of word
1	Berita Harian	9	317
2	Utusan Malaysia	11	263
3	Utusan Malaysia	10	303
4	Berita Harian	16	317
5	Berita Harian	9	244
6	BERNAMA	14	311
7	BERNAMA	6	203
8	Berita Harian	21	427
9	Utusan Malaysia	12	250
10	Utusan Malaysia	12	298

3.2 Group of Word Evaluation

The group of word labeling measurement accuracy technique is used to get the closeness of agreement between measured quantity value and a true quantity value. Table 6 shows the accuracy for the group of word labeling for noun, adjective, verb and number noun in the test set.

Table 6 –Word Group Labeling Results

Source	Accuracy (%)			
	Noun	Adjective	Verb	Number Noun
1-Berita Harian	87.76	63.64	77.78	88.89
2-Utusan Malaysia	90.91	75.00	85.71	100
3-Utusan Malaysia	86.81	91.67	90.91	90.91
4-Berita Harian	89.77	92.86	87.50	100
5-Berita Harian	92.21	77.78	97.67	85.71
6-BERNAMA	91.21	90.00	90.62	75.00
7-BERNAMA	79.54	85.71	93.10	100
8-Berita Harian	85.71	83.33	85.18	100
9-Utusan Malaysia	87.67	62.50	87.88	66.67
10-Utusan Malaysia	92.96	91.67	87.51	83.33
Average	**88.45**	**81.42**	**88.39**	**89.05**

According on Table 6, the average accuracy of group of word for noun is 88.45%, adjective is 81.42%, verb is 88.39% and number noun is 89.05%. Based on this results, the group of word labeling will be the foundation to the creation of concept, attribute and non-taxonomy relationship. However, the absence of word (lemma) in Malay Language System will affect the accuracy of word labeling. Adding to that, mislabeling on a group of words may also affect the accuracy of creation and detection of ontology components. For example, word 'terdahulu' is labeled as a verb whereas the semantically group of words is an adjective.

3.3 Taxonomy Relationship Detection Evaluation

The evaluation strategy is using model evaluation metrics to measure the quality of taxonomy relationship detection by using precision and the percentage of total relevant results correctly classified (recall). Table 7 shows the results of taxonomy relationship detection evaluation.

Table 7 - Taxonomy Relationship Detection Results

Source	Precision	Recall
1-Berita Harian	0.86	0.89
2-Utusan Malaysia	0.62	0.87
3-Utusan Malaysia	0.77	0.88
4-Berita Harian	0.70	0.76
5-Berita Harian	0.79	0.86
6-BERNAMA	0.82	0.92
7-BERNAMA	0.85	0.94
8-Berita Harian	0.93	0.95
9-Utusan Malaysia	0.77	0.86
10-Utusan Malaysia	0.81	0.87
Average	**0.79**	**0.88**

Table 7 shows the effectiveness of taxonomy relationship between concept detection with the average of precision is 79% and the average of recall is 88%. The results of the precision are low due to the use of comma punctuation in a sentence that lead to mislabeled the group of word. For example, sentence of 'Kata beliau rakyat di Bukit Gantang, Bukit Selambau dan Batang Ai juga...' is missing comma punctuation after the word 'beliau'. The missing comma punctuation is causing the system to produce the word label 'beliau rakyat', then form the taxonomy relationship between concept 'beliau' with sub-concept 'beliau rakyat'. Apart from that, the low results are also triggered by the issue of polysemy that has mislabeled the group of words. For example, 'Kesemua pelajar cemerlang terbabit menerima wang tunai RM300, dua buah buku motivasi dan sijil penghargaan' has mislabeled the word 'buah' as a noun although 'buah' is a collective noun. This polysemy issue is prompting the system to produce the word label 'buah buku'. The example of a taxonomy relationship gold standard is ~~as~~ shown in Table 8.

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Table 8 – Example of Taxonomy Relationship

Concept	Sub-concept
kejadian	*kejadian kematian*
pegawai	*pegawai kanan*
peringkat	*peringkat kajian*
lokap	*lokap polis*
dewan	*dewan negara*
langkah	*langkah penambahbaikan*
kemudahan	*kemudahan kamera*
sistem	*sistem pemantauan*
pegawai	*pegawai polis*

3.4 Attribute Relationship Detection Evaluation

The evaluation of attribute relationship detection is using the evaluation metrics model. Table 9 shows the results of attribute relationship detection evaluation.

Table 9 – Attribute Relationship Evaluation Results

Source	Precision	Recall
1-Berita Harian	0.52	0.70
2-Utusan Malaysia	0.58	0.79
3-Utusan Malaysia	0.69	0.83
4-Berita Harian	0.54	0.74
5-Berita Harian	0.64	0.83
6-BERNAMA	0.48	0.83
7-BERNAMA	0.60	0.90
8-Berita Harian	0.29	0.82
9-Utusan Malaysia	0.47	0.74
10-Utusan Malaysia	0.63	0.83
Average	**0.54**	**0.80**

Based on Table 9, the average precision is 54% and the average recall is 80%. The result of precision for attribute relationship is low due to the issues affected in the earlier evaluation (taxonomy relationship detection) which carry out poor value in both precision and recall for relationship between concept and attribute. Mislabeled group of words that has two nouns in a sentence will affect the accuracy of attribute relationship, for example '...insiden kematian atau kecederaan orang tahanan berulang'. MyOntologyGen detects two nouns group of word which are 'kecederaan orang' and 'tahanan', however it should detect two attribute relationship with 'orang tahanan', which are 'insiden kematian' and 'kecederaan'.

3.5 Non-Taxonomy Relationship Detection Evaluation

The strategy of non-taxonomy relationship detection evaluation is performed using model evaluation metrics by precision and recall. Table 10 shows the result of non-taxonomy relationship evaluation. The results show the effectiveness of non-taxonomy relationship detection between concepts is low with precision average is 63% and recall average is 60%. Precision and recall value in non-taxonomy relationship are dependent on evaluation results of taxonomy relationship and attribute relationship. There are different techniques in detecting the taxonomy and non-taxonomy relationship. The non-taxonomy relationship involves three descriptor relationships which are two nouns and one verb whereas taxonomy relationship and attribute relationship only involve two descriptors.

Table 10 – Non-Taxonomy Relationship Evaluation Results

Source	Precision	Recall
1-Berita Harian	0.82	0.64
2-Utusan Malaysia	1.00	0.88
3-Utusan Malaysia	0.70	0.64
4-Berita Harian	0.50	0.62
5-Berita Harian	0.59	0.68
6-BERNAMA	0.33	0.40
7-BERNAMA	0.67	0.46
8-Berita Harian	0.67	0.67
9-Utusan Malaysia	0.45	0.38
10-Utusan Malaysia	0.59	0.67
Average	0.63	0.60

The results also depend on the structure of the phrases. Some of the phrases have patterns that are causing the system to create the wrong non-taxonomy relationship. For example, 'Selain itu, pengalaman dan kreativiti guru-guru dalam...', the system has detected non-taxonomy relationship 'pengalaman' - 'kreativiti' - 'guru-guru' in which noun and verb are linked with conjunction word 'dan'. Hence, neglecting the comma punctuation before the sequence of verbs would also lead the system to identify the wrong non-taxonomy relationship.

Based on the results, there is an undetected attribute relationship that caused by attribute location is no to be near with concept in the sequence of words. On the other hand, noun descriptor is the highest number to become an attribute to a concept and action, followed by verb, adjective and number noun.

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4. Conclusion and Future Work

This paper presents the process of ontology creation which include group of word labels, formation of semantic descriptors and formation of relationships in ontology components. To evaluate the accuracy of ontology component creation, four evaluations have been performed against the gold standard. The finding analysis has shown that the detection of the ontology component depends on the accuracy of the group of word detection, and relationships of taxonomy with concept and relationships of attribute. To get the best ontology engineering, word group labeling needs to be identified precisely to extract the taxonomy and non-taxonomy relationships. According to the results, low performance of the accuracy has given the opportunity to acquire better results in ontology engineering. Future work will be focusing on improving group of word labeling and applying the semantic similarity in forming relationships between ontology elements.

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