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Multimedia Retrieval and Search Ranking Based on Domain Ontology

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Abstract

Multimedia plays an important role in today's IT world. Over the past few decades, a lot of research has been done for retrieval of multimedia content and annotation for semantic web. We present a framework for multimedia retrieval and search ranking strategy which exploits descriptive metadata as well as domain ontology. It supports semantic retrieval by combining ontological concepts and textual features extracted from annotation. In this paper a query processing model including a semantic expansion schema is used to extend the meaning of the user query, which aims at retrieving multimedia objects semantically. This procedure results in serval semantic expansion sets. The similarity between each set and the query words can be calculated. Based on the semantic expansion sets, multimedia can be retrieved. In addition, we discuss our search ranking algorithm. Since this paper is focused on multimedia rather than text, so the similarity of the expansions of word-sequence will be adopted to determine the sequence of results. Finally, the results of different experiments are quite promising in terms of retrieval accuracy and relevance.

Keywords: *Multimedia; Ontology; Semantic-based Search; Search Ranking*

1. Introduction

When a query is entered into a search engine, it returns the results which are normally ranked by the relevance to the query. Consequently, the most related results can be displayed on the first page and the best results are accessible on the top of the sequence or pages. This is the basic requirement for the semantic search engine. Using ontology-based semantic similarity, we propose a model for multimedia retrieval and search ranking.

The basic idea is that all materials indexed by the search engine must use a special set of tags, these tags provide more information including contents and relationships. But using the tags alone cannot solve the search problem as machine cannot understand the meaning associated with ordinary tags. This problem can be solved by using the ontology. The use of ontology to overcome the limitations of tag-based search has been put forward as one of the motivations of the semantic web since its emergence in the late 90's. An ontology is a formal naming and definition of the types, properties, and the interrelationships of the entities that really or fundamentally exist for a particular domain [1]. So the meaning of the query words can be extended according to the similar concepts in the ontology and known as semantic expansion. This procedure results in serval semantic expansion sets. The similarity between each set and the query words can be

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calculated. Based on the semantic expansion sets, multimedia can be retrieved and the results can be ordered by the similarity.

The rest of this paper is structured as follows: Section 2 discusses related work. Section 3 provides the details about semantic expansion and how to calculate the semantic similarity between the expansion set and query. Section 4 shows the experimental results based on the ranking algorithm. Finally, Section 5 gives the conclusions of this work.

2. Related Works

2.1. Methods on Search Ranking

Semantic search engine [2] adds semantic information based on the traditional one and it can combine the user's search intent with the context to make the search results more accurate. Semantic search engine considers the semantic relations, weight of the expansion words, the frequency of keywords appears in the document and other factors to determine the sequence of the results [3]. Since this paper is focused on multimedia rather than text, so the display sequence will be determined by the weight of the expansion words.

2.2. Ontology

According to [4] ontology model can be divided into tree-based ontology and graph-based ontology. TR (N, E) represents the tree-based ontology, N is the set of nodes and E is the edges connecting the nodes. For the tree-based ontology, every sub node belongs to only one parent. The semantic message that expressed by the siblings (in the same level) do not overlap with each other, it means the relationship between the siblings are measured by the same parent. TG (N, E) represents the graph-based ontology, N is the set of nodes and E is the edges connecting the nodes. The difference between tree-based ontology and graph-based ontology is that node in the graph-based ontology can have more than one parent.

For the tree-based ontology, sub node belongs to the parent. For example, considering the nodes Animal and Cat – Cat might be a subclass of Animal (so Animal is the superclass of Cat). This says that, 'All cats are animals', 'All members of the class Cat are the members of the class Animal'. It is the "is-a" relationship between the nodes. In the graph-based ontology, besides the "is-a" relationship, there exists "part-of" relationship between the nodes. Figure1 illustrates the relationships in the tree-based ontology.

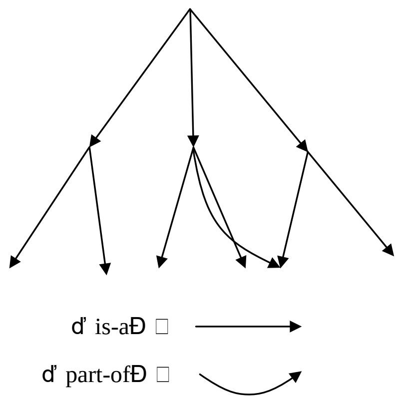

Figure 1. Relationships in Tree-based Ontology

In this paper, we use OWL ontology and use protégé to build an ontology. An OWL ontology [5] consists of Individuals, Properties, and Classes, which roughly correspond to protégé frames Instances, Slots and Classes.

2.3. Intelligent Retrieval System Based on Ontology

Since the ontology provides a method of organizing information and knowledge. In the process of constructing intelligent information retrieval systems, the vocabulary and description of the terms which need semantic annotation, and words which are used in representing the relationships between resources can be expressed in the ontology. When the retrieval tool requires inference reasoning, the relationships between all resources and constraints on the attributes of the conditions may be given by the ontology. Therefore, the ontology plays a significant role in the following aspects of intelligent retrieval system [6].

2.3.1. Semantic Annotation

Documents should be annotated according to the ontology, it means constructing the mapping relationships of concepts and vocabulary by analyzing the typical words in the documents. In this way, it will associate documents with the ontology, thus, expressing the implied semantic information in the documents explicitly.

2.3.2. Index with Ontology

Indexing the documents based on ontology means the index is generated on the basis of the text feature extraction, indexing text expresses the intrinsic link between the words. The ontology-based index consists of feature words and the relationship between each other which can be obtained from semantic annotation.

2.3.3. Retrieval Expansion with Ontology

Retrieval expansion means it can extend the user's query based on the semantic level, mainly utilizes the semantic relation of ontology and the reasoning mechanism. Thus, the retrieval system can better understand the user’s search intent and help the users to find the corresponding results. To a certain extent, it can make up the defects in inadequate query and improve the recall and precision rate in information retrieval system.

2.4. Calculate the Relationships between Concepts

In the early 1980s, people have researched on how to calculate the semantic similarity and semantic relevancy based on ontologies and proposed three representative theoretical approaches.

2.4.1. Based on Distance

The basic idea is that we calculate the semantic similarity based on the distance of path between two concepts. The most representative approaches are Shortest Path and Weighted Links [7].

2.4.2. Based on Properties

This method is based on a hypothesis that the more common properties will get higher semantic similarity. The main methods are proposed by Patwardhan [8] and Banerjee & Pedersen [9].

2.4.3. Based on Information Sharing

This method is based on a hypothesis that the more common information will get higher semantic similarity. The most representative approaches are proposed by Lord, Resnik and Jiang & Conrath [10].

3. Ontology-Based Semantic Similarity

3.1. Methods on Calculating Semantic Similarity

We proposed a comprehensive method to calculate the semantic similarity, and this method combines with four factors including ‘word similarity’, ‘semantic coincidence ratio’, ‘distance similarity’ and ‘hierarchy depth’. We discuss the four factors as follows.

Word similarity is only suitable for the Chinese characters. In Chinese, the words which have similar concepts may have same characters. So we can define the word similarity as the following formula.

$$wordSim(A,B) = \frac{wordNum(A \cap B)}{wordNum(A) + wordNum(B)} \tag{1}$$

where, $wordNum(A) + wordNum(B)$ is total number of the Chinese characters. $wordNum(A \cap B)$ is common Chinese characters in the words.

Semantic Contract Ratio can be defined as follows.

$$semCR(A,B) = \frac{nodeSet(A,R) \cap nodeSet(B,R)}{nodeSet(A,R) \cup nodeSet(B,R)} \tag{2}$$

where, $nodeSet(A,R)$ is the set of the nodes from node A to root node R. $nodeSet(B,R)$ is the set of the nodes from node B to root node R. Intersection between two sets means number of nodes in common, union denotes the all nodes in $nodeSet(A,R)$ and $nodeSet(B,R)$.

We define the distance similarity as follows: first, we should find the common parent of node A and B. If they don’t have common parent, it means node A and B are unreachable and we define the distance is 0. If they have common parent C, then we need to calculate the length to node A and B. $length(A,C)$ is the length from A to C and $length(B,C)$ is the length from B to C. The formula is expressed as follows.

When A and B are unreachable,

$$disSim(A,B) = 0 \tag{3}$$

When A and B are reachable,

$$disSim(A,B) = \frac{1}{|length(A,C) - length(B,C)| + 1} \tag{4}$$

Obviously, when A and B are siblings, $disSim(A,B) = 1$.

Suppose R is the root node in the ontology model, so hierarchy Depth can be defined as follows.

$$depH(A,B) = \frac{length(A,R) + length(B,R)}{2 * length(R)} \tag{5}$$

In this formula, $length(A,R)$ is the length from node A to root node R. $length(B,R)$ is the length from node B to root node R. $length(R)$ is the depth of the ontology model.

In summary, we combine the four factors to define the semantic similarity between two concepts.

When $A = B$,

$$sim(A,B) = 1 \tag{6}$$

When $A \neq B$,

$$\begin{aligned} &sim(A,B) \\ &= e_1 * wordSim(A,B) + e_2 * semCR(A,B) \\ &+ e_3 * disSim(A,B) + e_4 * depH(A,B) \end{aligned} \tag{7}$$

where e_1 is the weight of word similarity, e_2 is the weight of the semantic coincidence ratio, e_3 is the weight of the distance similarity and e_4 is the weight of depth and $e_1 + e_2 + e_3 + e_4 = 1$.

3.2. Determine the Parameters

However, to calculate the semantic similarity by using the formula (5), parameters should be determined in advance. In this section a method for determining the optimal parameters is proposed.

- Choose 20 concepts from the ontology and divide them into 10 groups.
- Calculate the similarity in each group, where is the similarity calculated by the formula (7) and is the similarity based on the subjective experience.
- Get the mean deviation.

$$\bar{\delta} = \frac{1}{10}\sum_{i=1}^{10}\delta_i \tag{8}$$

In this paper, we use three sets of data for this experiment and the results are depicted in Table 1-3. Table 1 shows the results with the parameters (e_1, e_2, e_3, e_4) equals (0.09, 0.28, 0.22, 0.41), Table 2 shows the results with the parameters (e_1, e_2, e_3, e_4) equals (0.06, 0.22, 0.38, 0.34) and Table 3 shows the results with the parameters (e_1, e_2, e_3, e_4) equals (0.09, 0.28, 0.22, 0.41).

When parameters (e_1, e_2, e_3, e_4) equals (0.09, 0.28, 0.22, 0.41), mean deviation will get the minimum value. So following formula will be adopted to calculate the similarity.

$$\begin{aligned} &sim(A,B) \\ &= 0.09 * wordSim(A,B) + 0.28 * semCR(A,B) \\ &+ 0.22 * disSim(A,B) + 0.41 * depH(A,B) \end{aligned} \tag{9}$$

Table 1. Results with Parameter Equals (0.09, 0.28, 0.22, 0.41)

Parameters	*A*	*B*	S_1	S_2	δ
e_1=0.09	Laptop	Computer	1	1	0.0
e_2=0.28	Cellphone	Landline	0.72	0.75	0.03
e_3=0.22	Filtered water dispenser	Banana tree	0.33	0.30	0.03
e_4=0.41	Desert	Ocean	0.40	0.45	0.05
	Volcano	Mountain	0.58	0.80	0.22
	Eagle	Resorts	0.33	0.40	0.07
	Aquarium	Science museum	0.61	0.60	0.01
	Animal	Subway	0.28	0.30	0.02
	Bird	Barrier	0.37	0.25	0.12
	Traffic	Zebra crossing	0.56	0.70	0.14
					Mean deviation：0.069

Table 2. Results with Parameter Equals (0.06, 0.22, 0.38, 0.34)

Parameters	*A*	*B*	S_1	S_2	δ
e_1=0.06	Laptop	Computer	1	1	0.00
e_2=0.22	Cellphone	Landline	0.56	0.75	0.19
e_3=0.38	Filtered water dispenser	Banana tree	0.30	0.30	0.00
e_4=0.34	Desert	Ocean	0.35	0.45	0.10
	Volcano	Mountain	0.60	0.80	0.20
	Eagle	Resorts	0.30	0.40	0.10
	Aquarium	Science museum	0.54	0.60	0.06
	Animal	Subway	0.25	0.30	0.05
	Bird	Barrier	0.34	0.25	0.09
	Traffic	Zebra crossing	0.46	0.70	0.24
					Mean deviation：0.103

Table 3. Results with the Parameter Equals (0.09, 0.28, 0.22, 0.41)

Parameters	A	B	S_1	S_2	δ
e_1=0.14	Laptop	Computer	1	1	0.00
e_2=0.32	Cellphone	Landline	0.58	0.75	0.17
e_3=0.19	Filtered water dispenser	Banana tree	0.33	0.30	0.03
e_4=0.35	Desert	Ocean	0.37	0.45	0.08
	Volcano	Mountain	0.57	0.80	0.23
	Eagle	Resorts	0.30	0.40	0.10
	Aquarium	Science museum	0.63	0.60	0.03
	Animal	Subway	0.26	0.30	0.04
	Bird	Barrier	0.13	0.25	0.12
	Traffic	Zebra crossing	0.43	0.70	0.27
					Mean deviation：0.107

However, we still need more specific explanation for the formula (9). If the query words are not included in the ontology, formula (9) should be divided into two steps. First, formula (10) is put forward to get the concepts in the ontology, which are similar to the query words.

$$sim_1(A,B) = wordSim(A,B) \tag{10}$$

Then, the second step is displayed as follows.

$$\begin{aligned} & sim_2(A,B) \\ & = e_2 * semCR(A,B) + e_3 * disSim(A,B) \\ & + e_4 * depH(A,B) \end{aligned} \tag{11}$$

In the formula (11), $e_2 + e_3 + e_4 \neq 1$, therefore, these must be changed according to the following rules.

$$e_2^{'} = \frac{e_2}{e_2 + e_3 + e_4}$$

$$e_3^{'} = \frac{e_3}{e_2 + e_3 + e_4}$$

$$e_4^{'} = \frac{e_4}{e_2 + e_3 + e_4}$$

where (e_1, e_2, e_3, e_4) equals (0.09, 0.28, 0.22, 0.41), then, $e_2^{'}$ = 0.31, $e_3^{'}$ = 0.24, $e_4^{'}$ = 0.45. Then, calculating the similarity with formula (12).

$$\begin{aligned} & sim_2(A,B) \\ & = 0.31 * semCR(A,B) + 0.24 * disSim(A,B) \\ & + 0.45 * depH(A,B) \end{aligned} \tag{12}$$

3.3. Semantic Expansion

In this paper, a process of semantic expansion is proposed based on [3]. The procedure is defined as follows. Firstly, query text should be processed in advance. This procedure results in a keyword set for the query text [11]. The keyword set is the initial expansion set. Secondly, make it clear whether or not each keyword is in the ontology. If the keyword is not in the ontology, we should use the formula (10) to find out the similar concepts in ontology, then, according to the formula (12) to find out concepts in ontology, whose concept similarity must be greater than threshold. If the keyword is in the ontology, we just use the formula (7) to find out the concepts in ontology, and the similarity between these concepts and keywords must be greater than the threshold. Finally add the concepts into the expansion set. Figure2 depicts the flowchart for the semantic expansion.

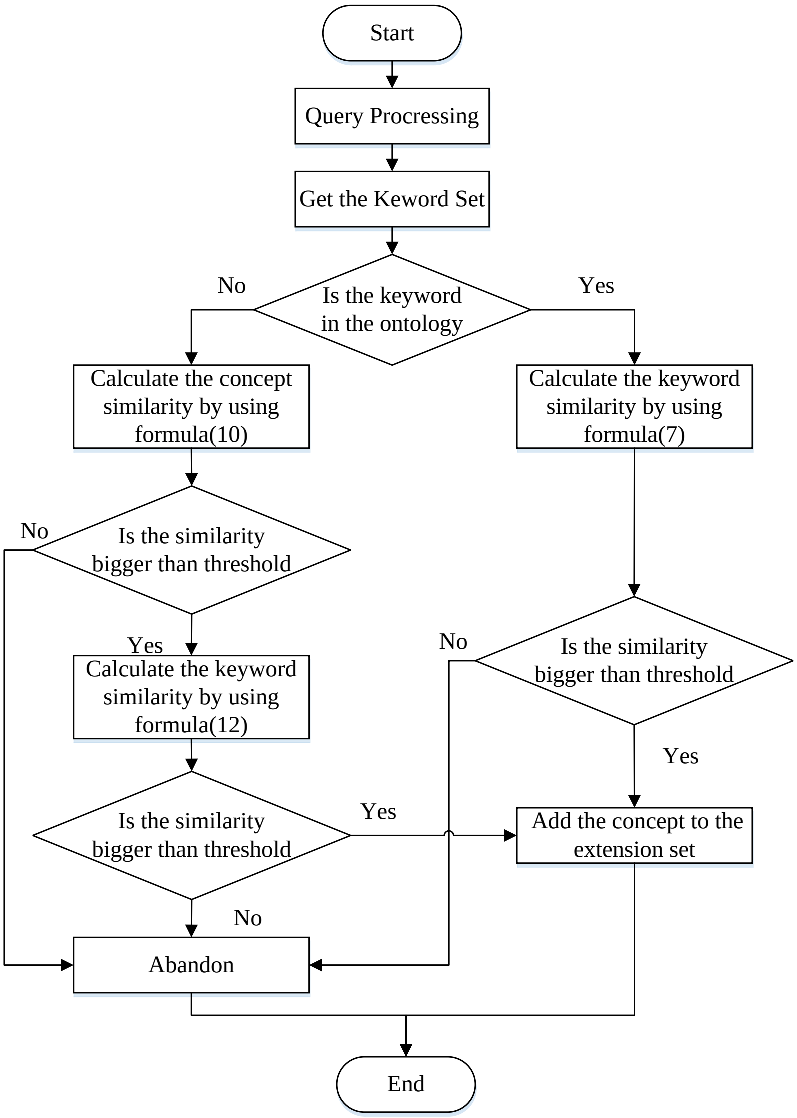

Figure 1. Flowchart for Semantic Expansion

4. Search Ranking

4.1. Factors for Search Ranking

Based on the query processing and semantic expansion sets, multimedia can be retrieved and the results are returned to the users in a particular sequence. In this paper we propose three ranking factors for the results.

Keywords: The keywords in the retrieval system are directly extracted from the query text or extended from the ontology is a significant factor for the search ranking. The keywords extracted from query text can express user's search intent directly. Although the keywords extended from the ontology satisfy the threshold condition, they still have biases with user's search intent. So the results which are associated with the keywords extracted from the query text should be displayed in the top of the sequence.

Similarity: The keywords extended from the ontology should satisfy the threshold limitation. A keyword with greater similarity means it is much closer to the user's search intent. So the similarity can be a criterion for the search ranking.

Number of Keywords: Sometimes we can only get one keyword from the query processing. It indicates that the user just wants to find a particular multimedia. If we get several keywords from the query processing procedure, it shows that the user just wants to find several types of the multimedia. The multimedia which are associated with several keywords will get the priority in the sequence.

4.2. Ranking Algorithm

In order to determine the sequence of the results we propose an algorithm for search ranking. The algorithm is based on concept similarity and keyword similarity. As we mentioned in Section 3, the keyword set can be divided into two parts. The first part is derived from the query processing and the another one is extended from the ontology. Each keyword in the second part has a weight to determine the sequence of results, and the weight is defined as follows.

$$weight(P) = sim(P, Q) \tag{13}$$

P is the keyword in expansion set, Q is the keyword in the first part and $sim(P, Q)$ is the result calculated by one of the above mentioned formulas (7,8,9). The weight for the keyword which is in the first part always equals 1.

If there is only one keyword in the first part, then the expansion set is derived from the single keyword. So the weight for the keyword in the expansion set can be calculated by using the formula (7). If it has more than one keywords in the first part, it will be more complicated. Suppose $A = \{K_1, K_2, \cdots, K_N\}$ is the first part of the keyword set. So the number of subsets in set A should be $2^N - 1$, and each subset must have a weight to determine the sequence. Because the search engine will return the results which are associated with a certain subset. This basic mechanism is based on a hypothesis that the system always tries to find the largest subset, *e.g.* “Shanghai University” is preferred to “Shanghai”. The weight for each subset is defined as follows.

$$weight(subset_i^n) = \sum_{j=1}^{n} x_j \tag{14}$$

where $subset_i^n$ is the ith subset in the set *A* which has *n* elements and x_j is the jth element in the subset.

4.3. Experiments and Results

We have tested our system with ten queries which can be divided into three groups. The query in the first group is the class in the ontology, the query in the second group is individual in the ontology and the query in the third group is phrase which consists of both class and individual. Table 4 shows the query data.

Table 4. Query Data

	Query Text	Attribute
Query a	Infrastructure	Class
Query b	Park	Class
Query c	Vegetable	Class
Query d	Sports	Class
Query e	Lily	Individual
Query f	Racket	Individual
Query g	Alps	Individual
Query h	News about technology	Phrase
Query i	Girl playing guitar	Phrase
Query j	Park with bench and trees	Phrase

In the field of information retrieval, precision is the fraction of retrieved documents that are relevant to the query, while recall is the fraction of the documents that are relevant to the query that are successfully retrieved.

$$P = \frac{TP}{TP + FP}$$

$$R = \frac{TP}{TP + FN}$$

where P is precision, R is recall, TP is the retrieved documents which are related to the query, FP is the retrieved documents which are not related to the query and FN is the related documents which are not retrieved in the system.

The F-measure of the system is defined as the weighted harmonic mean of its precision and recall, that is,

$$F = \frac{1}{\alpha\frac{1}{P} + (1-\alpha)\frac{1}{R}}$$

where weight $\alpha \in [0,1]$. The balanced F-measure, commonly denoted as F, equally weighs precision and recall, which means $\alpha = 0.5$. The F-measure can be written as,

$$F = \frac{2PR}{P + R}$$

The F-measure can be viewed as a compromise between recall and precision. It will be high only when both recall and precision are high. It is equivalent to recall when α = 0 and precision when α = 1. The F-measure assumes values in the interval [0,1]. It is 0 when no relevant documents are retrieved, and is 1 if all retrieved documents are relevant and all relevant documents have been retrieved. Table 5 displayed the results of the ten queries.

Table 5. Experiment Results

Query	Keywords Search			Semantic Search		
	TP	***FP***	***FN***	***TP***	***FP***	***FN***
a	12	17	9	18	5	3
b	39	66	50	82	8	7
c	25	16	22	38	10	9
d	43	59	65	95	25	13
e	10	23	9	16	2	3
f	16	21	25	32	12	9
g	31	53	22	45	5	8
h	9	34	5	14	15	0
i	6	8	5	11	20	0
j	22	38	15	37	51	0

The experiment results show that semantic search gets the higher precision and recall than keywords search we can only get one keyword after query processing, such as query a-g. The queries which have multiple keywords will get higher recall in semantic search. Because, the keyword set for the query will be extended, it means we can get more related multimedia. However, multiple keywords will decline the precision. Precision, recall and F-measure for the ten queries are displayed as Figure3-5. Figure6 shows the mean value for precision, recall and F-measure in keywords search and semantic search.

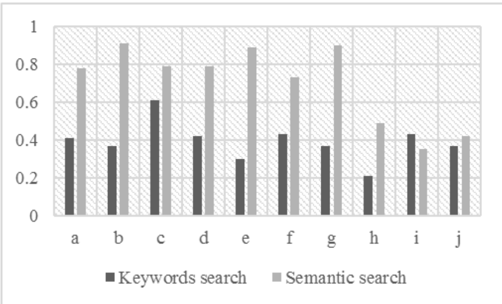

Figure 3. Precision

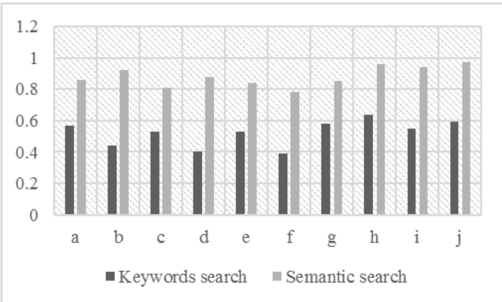

Figure 4. Recall

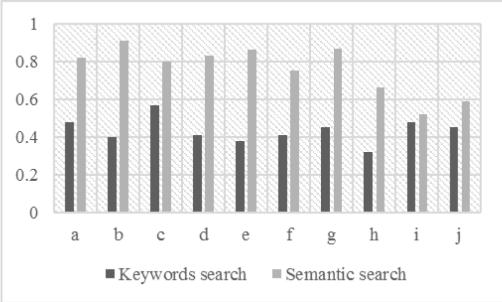

Figure 5. F-Measure

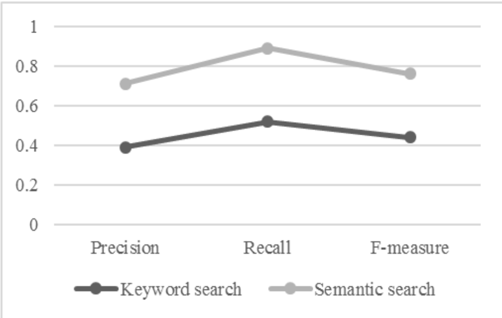

Figure 6. Mean Value for Precision, Recall and F-Measure

5. Conclusion

During the material retrieval, search results which are mostly related to the query contents are expected. This paper proposes an innovative semantic search method, which combines the ontology and search engine technology. First, a calculation formula that combines words similarity, semantic contact ratio, distance similarity and hierarchy depth is put forward. In order to determine the weights of the four factors, experiments for computing the concepts similarity are performed. Then the formula for search ranking is proposed based on the concept similarity. Finally, the results of different experiments are quite promising in terms of retrieval accuracy and relevance.

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