ENHANCING THE PERFORMANCE OF MULTI-MODALITY ONTOLOGY SEMANTIC IMAGE RETRIEVAL USING OBJECT PROPERTIES FILTER

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ABSTRACT. Semantic technology such as ontology provides the possible approach to narrow down the semantic gap issue in image retrieval between low-level visual features and high-level human semantic. The semantic gap occurs when there is a disagreement between the information that is extracted from visual data and the text description. In this paper, we applied ontology to bridge the semantic gap by developing a prototype multi-modality ontology image retrieval with the enhancement of retrieval mechanism by using the object properties filter. The results demonstrated that, based on precision measurement, our proposed approach delivered better results compared to the approach without using object properties filter.

Keywords: multi-modality ontology, semantic image retrieval, object properties filter, semantic gap

INTRODUCTION

Image retrieval (IMR) becomes an important research since the last four decades because the need to control and manage the collections of large images properly in many domains related to images (Rui, Huang, & Chang, 1999). The early stage of IMR method is called the text-based image retrieval (TBIR), which uses text associated with particular image to determine what the image contains (Riad, Elminir, & Abd-Elghany, 2012). Since there are several disadvantages of TBIR approach such as no standard image filling and consume large human effort, the content-based image retrieval (CBIR) is proposed. In CBIR, the images are retrieved through the indexing of low-level features such as colour, texture and shape. There are many algorithms that have been designed to describe the low-level features (Zhang, Islam, & Lu, 2012). However, these algorithms failed to model the image semantics as how humans interpret the images (Zhang, 2007). Therefore the semantic-based image retrieval (SBIR), has been proposed as a possible solution to bridge the semantic gap (Smeulders, Worring, Santini, Gupta, & Jain, 2000) between low-level features and high-level human semantic. A review was done by Liu, Zhang, Lu and Ma (2007) who discovered that ontology is one of the techniques available to narrow down the semantic gap. Therefore, we developed the multi-modality ontology (MMO) by assimilating the textual information and visual features to high-level concepts so that the human and machine are able to understand mutually. In this study, the herbal medicinal plant has been chosen as the case study since there is a significant demand from people around the world. World Health Organization (WHO) (WHO, 2008) stated that between 70% to 80% of developed countries have used alternative medicines for their

health. These high percentages portray the crucial of semantic descriptions for the herbal medicinal plant images to cater for such various users information need. Furthermore, this study explores the significance and the impacts of object properties filter which can be exploited in retrieval mechanism in order to achieve the main goals in IMR, to increase the relevant and accuracy of digital images retrieval.

RELATED WORK

Ontology can be defined as a formal depiction of a set of entities within a domain and the relationships among those entities. A formal ontology comprises a controlled vocabulary articulated in a representation language. This language has syntax in using vocabulary terms to label something meaningful within the interest of specified domain (Gruber, 1993). In the context of IMR research, ontology is used to define the high-level concepts using well-structured approach and relationships that are human readable and meaningful (Liu et al., 2007). For example, in some IMR systems, image descriptors are used to form a simple vocabulary such as light green, medium green and dark green (Mezaris, Kompatsiaris, & Strintzis, 2003). It provides a qualitative definition of high-level query concepts which are understood by human. Therefore, the ontology can assists the machines to analyze semantic visual information from various perspectives and provides unlimited descriptive power of semantics.

Ontology and Image Retrieval System

Some earlier CBIR proposed the concept of integrating high-level textual information and low-level features without considering the requirement of ontology which has the capability in providing an explicit domain-oriented semantics in terms of defining concepts and their relationships. Therefore, the MMO approach was proposed to enhance the previous studies in order to achieve the main goal in IMR. This concept was then exploited by several researchers in their respective IMR work. MMO is the integration of high-level textual information and low-level image features metadata to represent the image contents for image retrieval (Wang, Liu, & Chia, 2008). A number of studies (Khalid., Azman, & Noah, 2012;Kesorn, 2010;Singh, Goudar, Rathore, Srivastav, & Rao, 2013;Magesh & Thangaraj, 2011; Wang et al., 2008) have proved that the MMO can improve the retrieval performance to get more accurate results. Previously, researchers prone to adapt the single-modality approaches either TBIR or CBIR. However, due to the limitation of both approaches, the need to combine both approaches to form a multi-modality or hybrid approach has become critical. Wang et al., (2008) performed an experiment by comparing the traditional keyword-based, the single text ontology and the MMO. By using 4000 canine domain images as a sample, he found that the retrieval performance has improved for about 5 to 30 percent by combining the high-level textual information with low-level image features and introducing the domain ontology into the MMO as an important cue to solve the problems of semantic interpretation in image retrieval. Therefore, the MMO can provide better retrieval results compared to single ontology. Khalid. et al., (2012) proposed an improvement by integrating the MMO with DBpedia. The proposed method improved the performance of image retrieval by interlinking it with the Linked Data technologies. Web developers can make use of the rich source of information and the domain ontology to enrich their vocabulary control. Singh et al., (2013) utilized the MMO concept for the development of IMR for their respective images on medicinal dataset. Despite the fact that applying the MMO in IMR showed better results by comparing it with the keyword-based and the single ontology, there is still a gap in order to achieve the optimum result especially on the retrieval mechanism. Great attention were given to enrich the vocabulary of ontology to resolve the lack of metadata depth with the hope that user would retrieve the image successfully. However, there are lacks of studies in emphasizing the accuracy of retrieval mechanism especially when the user confronts with a large scale of image

metadata. Therefore, this paper will discuss the advantages of MMO approaches for herbal medicinal plant dataset by combining with object properties filter.

Object Properties

Object properties represent the relationships between two individuals in ontology. In common practice, the name of an object property starts with lower case letter, has no spaces, has remaining words capitalized and the name is unique. It is also recommended that properties are prefixed with the words 'has' e.g. *hasShapeFlower*, *hasFruitType*, and *hasRootHabit*. Usually, object properties have been used in establishing relationships in ontology (Noy & McGuinness, 2000). However, in this study we exploited the object properties to filter the initial retrieval results to be more accurate in terms of precision. For example, if our metadata have similar name in different classes, the results would reduce the performance of precision. Therefore, the object properties can be utilized to filter more accurate retrieval results and can improve the performance of precision.

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The Framework

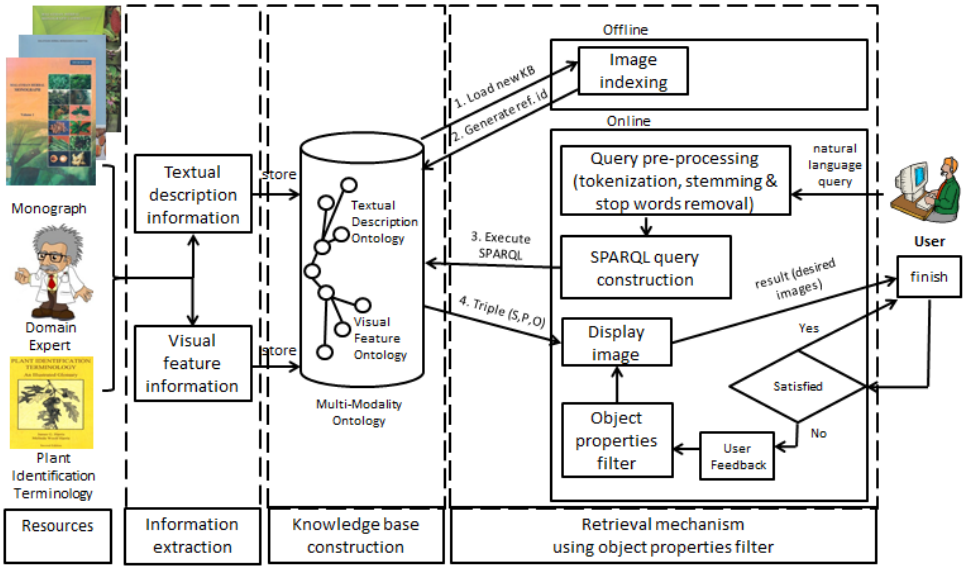

Figure 1. General Framework of Semantic MMO IMR with Object Properties Filter

Figure 1 depicts the general framework of MMO IMR system which consists of four main components which are resources, information extraction, knowledge base construction and retrieval mechanism using object properties filter. The resources component represent the identification of domain, scope, corpora and metadata. To clarify the contents of corpora, (Commitee, 1999, 2009, 2012) we consulted with domain experts in herbal medicinal plant. We also referred to the plant identification terminologies (Harris & Harris, 2004) to describe the classification of plant concept during the process of analyzing the potential class.

Information Extraction and Ontology Development

There are two types of information extraction performed which are analyzing the textual description information and interpreting the semantic visual feature information. The textual description information describes the high-level concepts of images. The textual information can be the facts from corpora that describe the particular herbal medicinal plant images. The extraction works began with collecting the information from the monographs with the assis-

tance of domain expert and by referring to the plant identification terminology. Other than that, formal interviews, brainstorming, formal and informal analysis are performed with the domain expert. We jotted down all the possible terms needed either to make a statement or to explain to the user. Then, we constructed the table template to enumerate the important terms in ontology, namely plant term worksheet. This worksheet is used in organizing the concept term. It is an output of the knowledge extraction for textual description information. To extract the semantic visual feature information, we adapted the method proposed by Wang et al., (2008). Firstly, we defined the set of terms adapted from corpora that are relevance to the image content. Then, we extracted the visual feature information that describes the low-level features information based on the particular herbal medicinal plant image. In this study, we used compact composite low-level features descriptors to extract the images such as Colour and Edge Directivity Descriptor (CEDD), Brightness and Texture Directionality Historgram (BTDH) and Fuzzy Colour and Texture Histogram (FCTH) because these outperform the MPEG-7 descriptors (Chatzichristofis, Zagoris, Boutalis, & Papamarkos, 2010). After that, we classified the images according to the XML index data from the extracted images using supervised machine learning. We used Bayesian network classifier since it can provide effective knowledge representation and inference engine in artificial intelligent (Serrano, Savakis, & Luo, 2004). Finally, each image has a set of tags to describe its content, which are matched with the concepts defined in the visual feature ontology.

Once all the textual description and visual feature information are extracted, we can proceed to construct the ontology. In order to construct the ontology, three important things must be defined which were the classes, properties and instances. In this study, the top-down approach adapted from Uschold and Gruninger (1996) is used. We started by identifying the most general concept in the domain and then continue with more specialized concept. Several classes are defined, including *Plant*, *Character*, *Odour*, *Physical*, *Taste*, *GeneralHabit* and *LeafPart*. The semantic relationships are generated to connect variety of concepts such as *hasColourFlower*, *hasFruitHabit*, *hasFlowerPart* and *hasLeafBases*. Finally, we manually created the relationship between *TextualConcept* and *VisualConcept* to be the MMO as depicted in Figure 2.

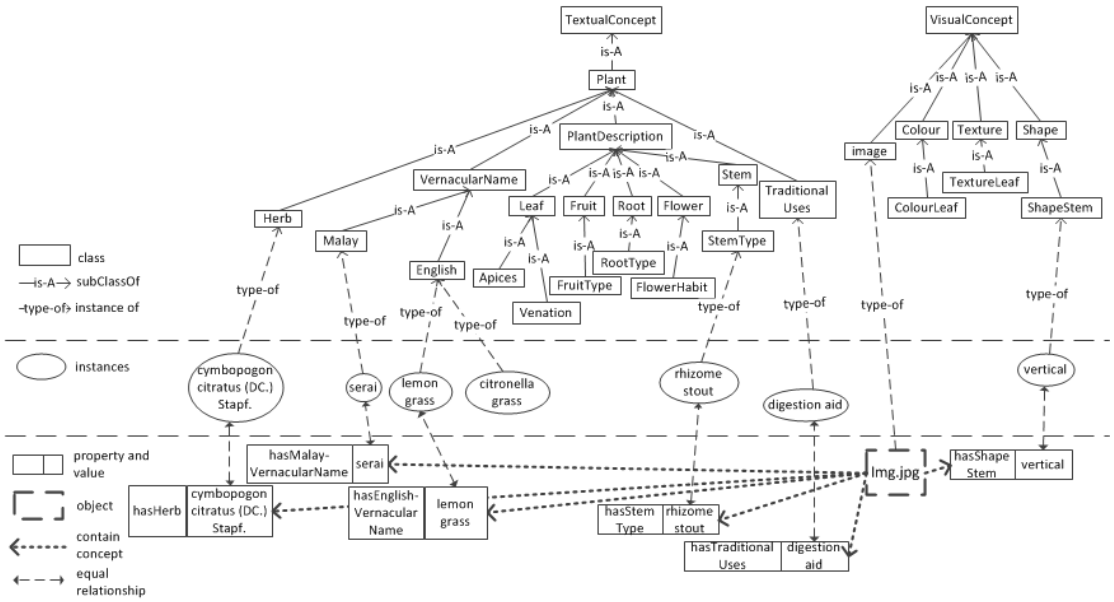

Figure 2. Structure of MMO

Retrieval Mechanism and Ontology Indexing

In the retrieval mechanism component, we utilized the natural language interface approach where the user can enter the natural language query to the interface. The natural language interface returns the desired images as required to the user if matched. Before the images can be retrieved from MMO, the images need to be indexed first. In the offline side, firstly, we loaded the MMO, then we indexed the images by generating five digits unique number as its reference id according to their image path. The Jena application programming interface (API) embedded with ARQ query engine has been employed to construct the search engine. The Liferay platform has been used to receive the natural language input query, to index the images and to display a set of matching images as a result to the user. The algorithm of semantic MMO IMR system is given in Figure 3, adapted from Kesorn (2010) with modification shown in step 3.1 to 4.

(1) Given the input query in natural language.
(2) Perform the query pre-processing e.g. tokenization, stop word removal and stemming (Porter Stemmer) to get a set of relevant query keywords.
(3) Based on the relevant query keywords, construct the Simple Protocol and RDF Query Language (SPARQL).
  (3.1) Identify the namespace of MMO.
  (3.2) Identify the instance based on related object (metadata).
  (3.3) Identify the image instance in the image class.
  (3.4) Identify the image id based on the image instance.
  (3.5) Identify the object properties according to image instance and instance.
  (3.6) Execute SPARQL based on identified instance, object, image instance, image id and object properties.
(4) If the query pattern did not match with MMO then
    Relevant images result = nullelse
    Display relevant images result based on the highest similarity score with dynamic object properties.

Figure 3. Semantic MMO IMR System Algorithm

In order to improve the precision of retrieval, we added a new ability to the existing algorithm which involved human as a part of the retrieval process as shown in Figure 4. The concept was quite similar to the relevance feedback (Sivakamasundari & Seenivasagam, 2012) approach. However, in relevance feedback, the user marked the queried images as a searched image that they wanted, but in our approach, the user will mark the object properties that are dynamically displayed with the queried images in the natural language interface. Then the marked object properties are fed back into the system as a new redefined query for the following cycle of the retrieval process. The operation can be repeated until the user becomes satisfied with the end query result.

(5) If the user is not satisfied with the initial retrieval result then
    Receive feedback from the user by selecting the dynamic object properties.
    Display the updated retrieval result.
  else
    Terminate the retrieval process.

Figure 4. Algorithm for Object Properties Filter

EVALUATION

To evaluate the retrieval performance of our semantic MMO IMR, we selected 60 species of herbal medicinal plant with 1114 instances, 3384 triples, 46 object properties, 61 classes and 180 images comprising the whole plant, leaf, flower, slender, stem, fruit, seed, root, bud, aerial and underground part images. We used the retrieval precision measurement where the number of relevant documents retrieved is divided by the total number of documents retrieved in that search. Let 'A' denotes all relevant images (as specified in a user query) in the image collection and 'B' denotes the retrieved images which the system returns for the user query. Precision (P) is defined as the portion of relevant images in the retrieved image:

$$Precision\ (P) = \frac{|A \cap B\ |}{|B|} \qquad (1)$$

We compared the image retrieval using the object properties filter and retrieval without using the object properties filter to benchmark the performance. We selected 5 natural language queries as a competency questions (Noy & McGuinness, 2000). Table 1 shows the list of the queries.

Table 1. List of Evaluation Queries

Queries	Natural language query
Q1	What is herbal medicinal plant that has entire leaf margins?
Q2	Find herbal medicinal plant that has aromatic smell?
Q3	What is herbal medicinal plant that can treat cough diseases?
Q4	Find herbal medicinal plant that has elliptic shape leaf?
Q5	What is herbal medicinal plant that has ovoid shape fruit?

We assessed the accuracy of our IMR by using precision measurement. Table 2, summarizes the results achieved. We compared the results between semantic MMO IMR using object properties filter (MMO-IMR-OPF) and the semantic MMO IMR without using object properties filter (MMO-IMR). Each of the precision number from Q1 to Q5 showed encouraging enhancement. According to the mean results, it showed improvement almost 30% of precision by utilizing the object properties filter. Through the experiment, we observed that, without using object properties filter, the user is still be able to retrieve the images as they wanted but the number of potential retrieved images would vary especially when the results of queried images are enormous. Therefore, we incorporated the MMO IMR with object properties filter to maximize the possibility to obtain the targeted images precisely.

Table 2. Evaluation Results

Queries	MMO-IMR				MMO-IMR-OPF			
	OP	C	R	P	OPF	C	R	P
Q1	*hasLeafPart, hasLeafMargins, hasLeafHabit, hasLeafDivision*	14	21	0.6667	*hasLeafMargins*	14	14	1.0000
Q2	*hasOdourCharacter,*	23	36	0.6389	*hasOdourCharacter*	23	33	0.6970

	hasFruitHabit, has-LeafHabit, hasSy-nonym							
Q3	*hasTraditionalUses*	6	9	0.6667	*hasTraditionalUses*	6	9	0.6667
Q4	*hasShapeLeaf, has-LeafHabit, hasLeaf-Part, hasShapeFlower*	22	31	0.7097	*hasShapeLeaf*	22	22	1.0000
Q5	*hasDefinition, has-ShapeFruit*	4	12	0.3333	*hasShapeFruit*	4	4	1.0000
Mean				0.6031				0.8727

*C=Correct, R=Retrieved, P=Precision, OP=Object Properties, OPF=Object Properties Filter

CONCLUSION

This paper presents an enhanced MMO IMR by incorporating with object properties filter. The empirical results of our MMO IMR produced more accurate results in terms of precision. Object properties filter played an important role to increase the accuracy of IMR effectively. We are currently finalizing another five additional complex queries to test the reliability and robustness of MMO IMR.

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