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The Study on the Semantic Image Retrieval based on the Personalized Ontology

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Abstract

Many approaches for retrieving the images semantically have been proposed. There still have many known limitations. The key problem is the identification of appropriate concepts. In this paper, we introduce the new image retrieval system that employs a concept based technique utilizing ontology. There are many attempts to search images using ontology. However, they haven't given the much good results. The reason is that the ontology just has been used to resolve the conceptual heterogeneous between the text annotations. Another reason is to use the much big ontology. To improve the accuracy in terms of precision and recall of an image retrieval system we have created a personalized ontology and spatial ontology. In trial implementation of our system we have achieved a level of accuracy at which was up to 83.9%.

1 Introduction

The development of technology in the field of digital media generates huge amounts of multimedia data, such as images, video and audio. Thus, storing and retrieving the non-textual information becomes the very important tasks. In here, we focus on the management of the images. There are many attempts to manage the image effectively. The traditional image retrieval employs contents-based search technique based on color, histogram, texture or shape features[1]. However, the search results become less accurate. In order to address the shortcomings of traditional techniques, many researchers have designed and implemented a concept-based model using ontologies[7][10]. But it also has not given the good results. The reason is that the ontology just has been used to resolve the conceptual heterogeneous between the text annotations. Another reason is to use the too big ontology in the concept based model. In this paper, we have designed and implemented the semantic image retrieval system using the personalized ontology and spatial ontology. The idea of using personalized ontology to help improve image retrieval techniques presents two main features: one is that users build the ontology themselves as they use their knowledge. And the ontology will become the personalized ontology. Other is to use the spatial ontology for representing the contents about the image more specifically.

In the 2nd chapter, we introduce the related researches about the image retrieval techniques – keyword-based and ontology based image retrieval. Then in chapter 3, we explain the main features of our system. And we test and evaluate our system as we compare with the existing systems in chapter 4. In the end of this paper, we conclude our study and suggest the future works.

2 Related Works

To place our research in the context of information retrieval effectiveness (precision and recall), we would like to summarize key related efforts. First, we will discuss a traditional keyword-based technique and then, a concept-based model using ontologies of the type we employ in order to overcome the shortcomings of a keyword-based search.

The typical way to publish an image data repository is to create a keyword-based query interface to an image database. Keyword-based search is useful especially to a user who knows what keywords are used to index the images and therefore can easily formulate queries[2]. This approach is problematic, however, when the user does not have a clear goal in mind, does not know what there is in the database, and what kind of semantic concepts are involved in the domain. Also, this retrieval methods suffer form other limitations: A keyword in a document does not necessarily mean that the document is relevant and relevant document may not contain the explicit word. Synonyms lower recall rate, homonyms lower precision rate, and semantic relations such as hyponymy, meronymy, antonymy are not exploited.

As mentioned in above section, the traditional information retrieval systems have the mismatch problem between the terminologies. For solving the problem, many researchers have studied to apply the ontology theory. A great many work showed that ontologies could be used not only for annotation and precise information retrieval [5], but also for helping the user in formulating the information need and the corresponding query. This is important especially in applications where the domain semantics are complicated and not necessarily known to the user. Furthermore, the ontology-enriched knowledge base of image metadata can be applied to constructing more meaningful answers to queries than just hit-lists.

But, this is not easy. The major difficulty in the ontology-based approach is the extra work needed in creating the ontology and the detailed annotations. We believe, however, that in many applications this price is justified due to the better accuracy obtained in information retrieval and the more semantic browsing facilities offered to the end-user. We are trying to implement semantic techniques to avoid so much hard work with the ontology building--the trade--off between annotation work and quality of information retrieval can be balanced by using these less detailed ontologies and annotations. Although this approach could address the mismatch problem between the terms, it is not the most suitable for image retrieval system because they did not consider the features of the image data. Therefore, we should not expect the good results in the ontology-based image retrieval system.

2.1 Survey about the Ontology-based Information Retrieval Systems

KIM, very close to the ontology-based information retrieval system, focuses on automatic annotation of documents. KIM is one of the most complete proposals for building high-quality KBs. In fact, KIM [13][16] relies on a keyword-based IR engine for this purpose such as indexing, retrieval and ranking. TAP [12] tries to address the two main problems are i) the development of a distributed query infrastructure for ontology data, and ii) the presentation of query execution results. However the expressive power of the TAP query language is fairly limited compared to ontology query languages such as RDQL, RQL, etc. Mayfield and Fin [15] combine ontology-based techniques and text-based retrieval. Documents are annotated with RDF triples, and ontology-based queries are reduced to boolean string search, based on matching RDF statements, at the cost of losing expressive power for queries. Semantic Portals [11,14] typically provide simple search functionalities that may be better characterised as semantic data retrieval, rather than semantic information retrieval. Searches return ontology instances rather than documents, and no ranking method is provided. Like above systems, there are many ontology-based retrieval systems, however, it still does not give the good retrieval results.

3 The Features of Our System

Our system has two core features for addressing the problems that existing ontology-based image retrieval systems have. One feature is to use the personalized ontology that is constructed by the users directly while they store the image information. The other feature is to adopt the spatial ontology for representing the spatial relationships between objects in the image. It helps more semantic descriptions about the image.

3.1 The First Feature – Personalized Ontology Usage

The main goal of the ontologization process was to create an ontology is suitable for the image exhibition. The different point between our system and other ontology-based system is that our system uses the personalized ontology. The definition of the personalized ontology is that the users build the new ontology about their interesting parts using their professional knowledge. In our system, we provide just the top-level ontological categories depicted in the left part of figure 1. And users can write the new ontology while they describe the images throughout our system automatically. Thus, users can build the ideal personalized ontology. And we expect it support the semantic image retrieval. For example, the user who is very interested in the soccer players wants to manage all images about soccer players.

In our system, the user can build the new ontology about the soccer players using his personal knowledge. At that time, the information about the images that user input adds to the top-level ontology. Thus, the top-level ontology is becoming big and personalized ontology. The ontology about the image is created and stored in the repository. In here, we assume that a user wants to store the image about 'Ronaldo' who is a soccer player using our system. Firstly he finds the 'Ronaldo' images from the web or other media, and then, he describes the information about the image. The user has much knowledge about the soccer players. 'Ronaldo' is a man and Brazilian and a black. Also, he is a soccer player for Brazil and belongs to the Spain Madrid soccer team. When the user finds the image, this information is stored together based on user's knowledge. So, there will be existed two kinds of ontologies. One is the ontology about the image information. The other is the top-level ontology that is added some information about 'Ronaldo' as the user describes the images. Figure 1 illustrates how to be changed the top-level ontology to the personalized ontology after adding the information about the images.

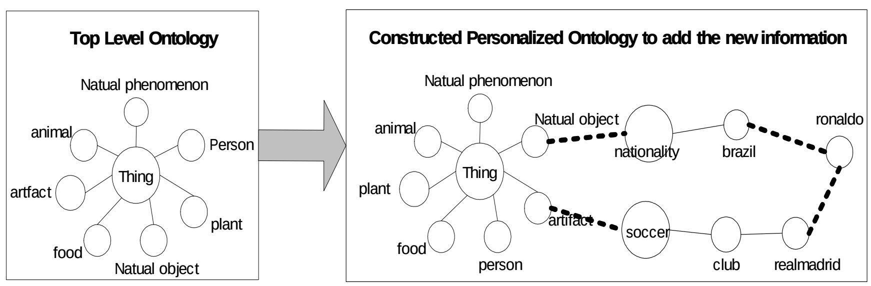

Figure 1. This figure illustrates how to change the top-level ontology when the user describes the 'Ronaldo' image throughout our system.

Like this step, the user continues to describe the images and top-level ontology is getting big and specific. Thus, we can expect the personalized ontology contributes the more semantic image retrieval. Table 1 shows the ontology that is representing the information about the 'Ronaldo' image.

Table 1. The Ontology about ‘Ronaldo’ image

```
<rdf:RDF  xmlns:owl = "http://www.w3.org/2002/07/owl#"
          xmlns:rdf = "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
          xmlns:rdfs = "http://www.w3.org/2000/01/rdf-schema#"
          xmlns:xsd = "http://www.w3.org/2001/XMLSchema#"
          xmlns:spr = "http://vector.chosun.ac.kr/spatial-relation#"
          xmlns:etc = "http://vector.chosun.ac.kr/etc#">

 <owl:Class rdf:ID = "artifact">
    <rdfs:subClassOf rdf:resource = "thing"/>
 </owl:Class>
 <owl:Class rdf:ID = "nationality">
    <rdfs:subClassOf rdf:resource = "artifact"/>
 </owl:Class>
 <owl:Class rdf:ID = "brazil">
    <rdfs:subClassOf rdf:resource = "nationality"/>
 </owl:Class>
 <owl:Class rdf:ID = "sports">
    <rdfs:subClassOf rdf:resource = "artifact"/>
 </owl:Class>
 <owl:Class rdf:ID = "soccer">
    <rdfs:subClassOf rdf:resource = "sports"/>
 </owl:Class>
 <owl:Class rdf:ID = "club">
    <rdfs:subClassOf rdf:resource = "soccer"/>
 </owl:Class>
 <owl:Class rdf:ID = "realmadrid">
    <rdfs:subClassOf rdf:resource = "club"/>
 </owl:Class>
 <owl:Class rdf:ID="ronaldo">
    <owl:intersectionOf rdf:parseType="Collection">
       <owl:Class rdf:about="realmadrid" />
       <owl:Class rdf:about="brazil" />
    </owl:intersectionOf>
 </owl:Class>
 <owl:Class rdf:ID = "1108529986093.owl">
     <etc:ImageAddress rdf:resource = "5506.jpg">
 </owl:Class>
</rdf>
```

3.2 The Second Feature - Spatial Ontology Usage

In section 3.1, we couldn’t address one problem of the ontology-based image retrieval system. It is to represent the contents about the image. There are various objects in the image and it needs to describe objects with spatial relationships for more correctly representing the images. As time goes, users give more complex queries and want to get more correct results directly. For example, the users use the simple query like as ‘Ronaldo’ to search the images about ‘Ronaldo’. Nowadays users want to find the correct images more complex query like as ‘Ronaldo shoot the ball’. For satisfying the user’s desire, the spatial ontology is necessary.

In this paper, we adopt the topological relationships that are related to how objects interconnect. The basic eight topological relationships (*RCC-8*)[12] consists of 'DC(disconnected)', 'C(connected)', 'PO(part-of)', 'TPP(tangential-proper-part-of)', 'NTPP(non-tangential-proper-part-of)', 'TPP^{-1}', '$NTPP^{-1}$' and 'EQ(equal)'. We choose the four primitive topological relationships among them. We think that the four relationships are sufficient to represent the spatial relationships among the objects in the images. Figure 2 shows the steps that we select the four topological relationships from the eight relationships.

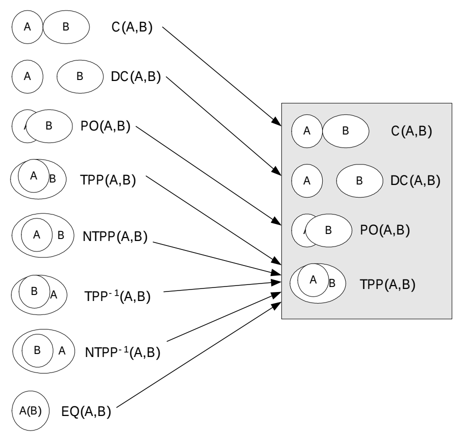

Figure 2. New four topological relationships

In our image retrieval system, we use the four topological relationships as the spatial relationships primitives. And each relationship has the specific properties. C(A,B) and DC(A,B) have the symmetric property and PO(A,B) has the transitive property. These properties help the system more semantically working. Based on the spatial relationships and their properties, we build the spatial ontology using the web ontology language(OWL)[9]. The table 2 shows the spatial ontology written by OWL.

Table 2. The Spatial Ontology

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
         xmlns:owl="http://www.w3.org/2002/07/owl#"
         xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
         Xmlns:sr="http://vector.chosun.ac.kr/spatial-basic#">
 <rdfs:comment>This ontology defines constructs for expressing spatial
        relations based on the Region Connection Calculus (RCC).</rdfs:comment>
 </owl:Ontology>
 <owl:Class rdf:ID="SpatialRegion">
   <rdfs:label>SpatialRegion</rdfs:label>
 </owl:Class>
 <owl:ObjectProperty rdf:ID="connectsWith">
   <rdfs:label>connects</rdfs:label>
   <rdfs:domain rdf:resource="#SpatialRegion" />
   <rdfs:range rdf:resource="#SpatialRegion" />
   <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty" />
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="disconnectedFrom">
   <rdfs:label>isDisconnectedFrom</rdfs:label>
   <rdfs:domain rdf:resource="#SpatialRegion" />
   <rdfs:range rdf:resource="#SpatialRegion" />
   <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#SymmetricProperty" />
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="partOf">
   <rdfs:label>partOf</rdfs:label>
   <rdfs:domain rdf:resource="#SpatialRegion" />
   <rdfs:range rdf:resource="#SpatialRegion" />
   <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#TransitiveProperty" />
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="tangentialProperPartOf">
   <rdfs:label>tangentialProperPartOf</rdfs:label>
   <rdfs:domain rdf:resource="#SpatialRegion" />
   <rdfs:range rdf:resource="#SpatialRegion" />
 </owl:ObjectProperty>
 </rdf:RDF>
```

4 Test and Evaluation

4.1 The System Architecture and Experimental Results

In this section, we test our system based on this scenario. A user who is very interested in the soccer players and has much knowledge about them wants to build the ontology about the soccer players with their images. The users firstly find the images about the soccer players from the web or others. And our system supports to build the ontology. When the user finds the images about the soccer players, new information will be added in the top-level ontology.

Figure 3 illustrates its appearance on our system.

Figure 3. The left part shows the images that get from the web. The part below the image helps to describe the images as ontology type. The right part shows the ontology that is written by ontology language about the images and shows the personalized ontology.

Throughout our system, we store many images about the soccer players and build the personalized ontology about the soccer players. We test our system and we could get the efficient retrieval results. We test about various query styles from the simple query like as 'Ronaldo' to the complex query 'The soccer player who is a Brazilian and is member of Spain Madrid soccer team'. Next Figures show the experimental result about the various queries.

Figures 4. The results about the query that is 'brazil soccer player'

Figure 5. The results about the query that is 'brazil soccer player and member of fc barcelona'

Figure 6. The results about the query that is 'korea soccer player and member of yokohama'

4.2 Evaluation

In this paper, we try to address the problems of the existing image retrieval system, especially the limitation of the ontology-based image retrieval. In here, we measure the retrieval accuracy for evaluating our system as we compare with our system, text annotation image retrieval and ontology-based image retrieval.

We use three test systems.

1. The text annotation based image retrieval that general is used in the web[Google].
2. The ontology based image retrieval that uses the WordNet[10].
3. The personalized ontology based image retrieval that we suggest in this paper.

And we prepare the nearly 1000 images about the soccer players and five kinds of queries for testing.

1. Ronaldo images
2. Brazilian soccer player
3. Soccer player who was born in Brazil and is member of Madrid soccer team
4. Goal images
5. Brazilian soccer player shoot the ball

And then, we measure the accuracy of each system. Because each system has the different image set, we just check the retrieval results about each system. For measuring the accuracy, we use the simple formula showing as below:

$$\textbf{Accuracy} = \frac{\textbf{Correct images matched with the query}}{\textbf{All images searched throughout the system}}$$

Table 3 shows the result about the test.

Table 3. The accuracy of each system about the various queries

Queries / System	1	2	3	4	5	Total Accuracy
1	0.613	0.493	0.375	0.843	0.1	0.484
2	0.723	0.875	0.617	0.762	0.1	0.615
3	0.659	0.931	1	0.893	0.712	0.839

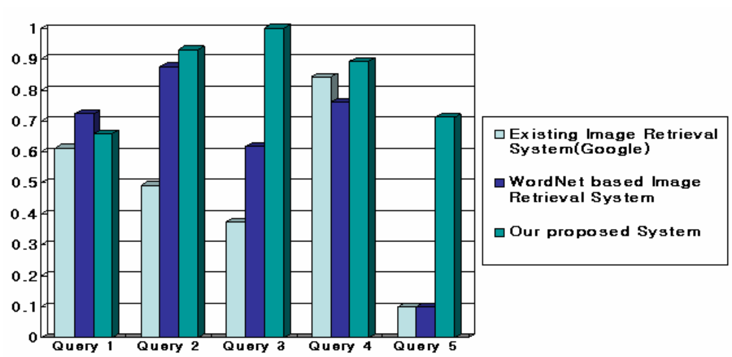

Figure 7. The results of the accuracy about the various queries

As we know in table 3 and figure 7, we could get the highest accuracy in our proposed system. Thus, we could expect that the personalized ontology and spatial ontology help search the images more semantically and correctly.

5 Conclusion and Future Works

The significance of our study tries to address the limitation of the ontology-based image retrieval system. For solving the problems, we build the personalized ontology and use it for the semantic retrieval. And we construct the spatial ontology for more specifically describing the contents of the images. In the section 4, we could know that our system provides improved performance throughout the test. However, our system has the problem that needs too much time to describe about the image. It remains our future works.

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