Image Ontology Construction using Spatial and Temporal Relationships

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Abstract: Semantic Web uses ontology structure for annotating any kind of information. The image representation and retrieval is a crucial task in the Semantic Web (Berners-Lee, 2001). Specifically, the Content Based Image Retrieval (CBIR) is used in retrieving the image using low level image features. The semantic gap is an unresolved problem in image retrieval. The ontology based image representation and retrieval methods are used to reduce the semantic gap. An image file consists of various objects in two dimensional space where each object is having some relationship with each other. The present search engines are not considering the relationship between the objects in an image. These relationships are expressed by using spatial methods like Region Connection Calculus (RCC) and Topological relationship. The tool ICONCLASS is used in the identification of various objects present in an image. The temporal data such as time and date are annotated to the ontology structure. This paper provides a method of constructing an image ontology using spatial and temporal relationship exist between the objects present in the image and method of retrieving the images using these relationships.
[N.Magesh, P.Thangaraj. **Image Ontology Construction using Spatial and Temporal Relationships.** *Life Sci J* 2013;10(3):121-129]. (ISSN:1097-8135). http://www.lifesciencesite.com 20

Keywords: Ontology, Region Connection Calculus, Image retrieval, SPARQL, RDF, Spatial relationship. Temporal relationship and Topological relationship

1. Introduction

Ontology is a knowledge representation technique used in Artificial Intelligence (AI). The knowledge based (ontological) approach is used to provide an explicit domain-oriented semantics in terms of defined concepts and their relationships that are not only machine-readable but also machine processable. The important image retrieval methods are Text Based Image Retrieval (TBIR) and CBIR. TBIR uses textual keywords to describe an image. The keywords such as Filename, Creator, Theme, Place and Date are used in describing the image content. CBIR is an efficient technique that considers low-level features such as Color, Texture and Shape of an image, In CBIR, numeric values are used to describe the content of an image. The Ontology Based Image Retrieval (OBIR) combines TBIR and CBIR along with the relationship among data (Magesh and Thangaraj, 2013). The ontology encodes descriptions of different concepts and relationships among them. Specifically, if the spatial and temporal relationships are added as the part of the ontology, then the retrieval rate of relevant image can be improved. Moreover, the queries are answered by means of context sensitive manner. It can be achieved by means of semantic image representation using spatial and temporal relationship. A practical method to reduce the manual annotation has been presented efficiently.

2. Related Work

Brewster et al (2004) provides the way to organize the information in a structured manner. It can be viewed as a level of abstraction of data models, analogous to hierarchical and relational model, but intended for modeling knowledge about individuals, their attributes and their relationship to other individuals. It defines a set of representational terms called concepts or categories. An image ontology is constructed for a natural image domain which includes the text (keyword) based features and content based features.

Schreiber et al. (2001) describe a method about using ontologies for photo annotation and agent operation on the ontology. The guidelines for using web standards in the Semantic Web are given. This also gives information about annotating photographs using multimedia information and gives a detailed analysis on querying photographs using the multimedia information analysis tool. This paper briefly outlines the advantages of ontologies over keywords based methods.

Allan Hanbury (2008) in the journal Science Direct has presented the image annotation using free text, keyword and ontologies along with the automatic generation of image metadata for content based image retrieval. The various image annotation methods are shown by utilizing tools such as ICONCLASS and WordNet.

The QACID is an ontology based Question Answering system applied to the Cinema Domain

(Ferrandez et al., 2009). This system allows users to retrieve data from formal ontologies by using input queries formulated in natural language. The original characteristic of QACID was the strategy used to fill the gap between users' expressiveness and formal knowledge representation.

The present ontology based representation and retrieval methods do not consider the relationship between the object in an image file. This paper strongly emphasizes the method of creating spatial relationship among the objects. This will contribute to taking a more specific image among several images. The OBIR methods are mostly improving the precision value in image retrieval. If the ontology uses the spatiotemporal relationships, the recall value is also be improved in the image retrieval.

3. The Proposed System

The spatiotemporal relationships are used to provide space and time related information of an image. The image contents are analyzed and the relationship between the content (Objects) are given by means of spatial relationship. If the spatial and the temporal dimension are integrated into the part of ontology, the image representation level is uplifted to the new dimension. The knowledge base becomes fully the time and space aware of, knowing not only that a fact is true, but also when and where it is true. The natural images may represent some part of geographical locations which need some crucial property not just of physical entities such as countries, mountains or rivers, but also be of organization headquarters or events such as battles, fairs or people's births. This paper concentrates on the way to reduce the semantic gap in the image retrieval system by using the spatiotemporal relationship.

3.1 Spatial Relationship

The spatial information describes the regions of space. The digital image consists of various objects in two dimensional spaces as pixels. The objects are linked by using spatial relationships which are conveyed by using the Region Connection Calculus (RCC) and Topological relationship.

3.1.1 Region Connection Calculus

The Region Connection Calculus (RCC) is used for representing qualitative information in spatial representation. The RCC abstractly describes regions in Euclidean space by their possible relations to each other. The RCC consists of eight basic relations existing between any two regions. They are 1) disconnected (DC), 2) externally connected (EC), 3) equal (EQ), 4) partially overlapping (PO), 5) tangential proper part (TPP), 6) tangential proper part inverse (TPPi), 7) non-tangential proper part (NTPP), 8) non-tangential proper part inverse (NTPPi).

The meaning of RCC is given below

1. DC (disconnected) means that the two regions do not share any point at all.
2. EC (externally connected) means that they only share borders.
3. PO (partially overlapping) means that the two regions share interior points.
4. TPP (tangential proper part) means that one region is a subset of the other sharing some points along the margins. The Venn diagram representation for RCC 8 is shown in **Figure** 1.

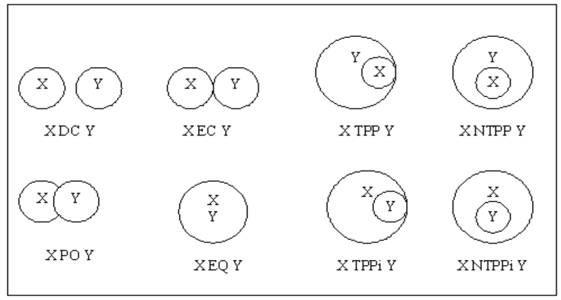

Figure.1 Diagrammatic View of RCC

The human thought process is described by using cognitive relationship (Russel and Norvig., 2003). The eight RCC relations are minimized to three cognitive spatial relationships as shown in **Figure** 2.

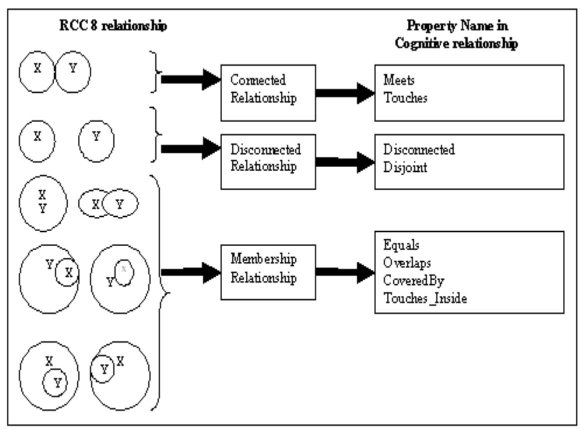

Figure 2 - RCC 8 relations are reduced to 3 cognitive relationships

3.1.2 Topological Relationships

The topological relationship is also used to express the some quantitative information in spatial representation. The important topological relationships are described as follows:

1. Proximity describes how close or how far away two (or more) objects are.
   - The snake is 5 feet away from the child
2. Orientation describes the location and direction of an object
   - The house is 10 miles north of the city
3. Connectivity means how two objects are linked with each other

- Every cottage in the LAL Park is connected by a subway of two feet wide.

4. Adjacency explains whether two objects are next to each other or not
   - The Murugan's house is next to Raman's
5. Membership means whether an object belongs to a particular group or not
   - Apple is a type of fruit.

In this paper, the one or more relationships exist between the objects in an image file are identified and these relationships are expressed by using spatial properties. The quantitative information consists of weight values. They are expressed as a sub property of a property. The sentence " The Bird can fly over the sky " is expressed by using the property Flie_over. Now, the bird is covered by sky. It is an NTTP relation. So the rule interpreter will apply the concept for the Swan. Hence " The Swan can fly over the sky " is interpreted as true. The **Fig 3** shows the spatial relationship for the classes. The direction and height are specified as a sub property of Flies_Over.

Flies_Over
direction = "north"
height_of = 5 feet

Consider the following Sentences.

1. Swan and River
2. The swan is surrounded by water
3. The swan is swimming in the river
4. The swan is swimming in the water
5. The swan is flying
6. The swan is flying over the river
7. The swan is flying over the river at the height of 2 feet
8. The swan is flying towards the north
9. The swan image is added on 01-02-2013
10. The swan images taken in the Lal park garden from 01-02-2012 to 31-01-2013.

The above ten sentences represent different meaning in human semantic level. The present day search engine considers the above quires as " swan + river + swim " and does not consider the semantic meaning of the sentence. The first eight sentences represent the spatial relationship and the last two sentences represent a temporal relationship. If the spatial and temporal relationships are included as the part of ontology, the above quires can be answered in a semantic manner. **Table** I gives the information about the various statements and its spatial properties with respect to cognitive relationship.

Table I – Region Connectivity Relation and properties

S.No	Example	Region Connectivity Relation	Meaning	Property
1	Swan and River	disconnected (DC)	Swan, River	Disjoint
2	The swan is surrounded by water	non tangential proper part (NTPP)	Swan is_covered by Water	Covered by
3	The swan is flying	non tangential **pro**per part (NTPP)	Bird can fly over the Sky	Covered by
4	The swan is flying over the River	disconnected (DC)	Swan is not connected with the River	Disjoint by
5	The swan is flying over the River at the height of 2 feet	disconnected (DC) (Use of topological relationship)	Flies_Over height_of = 2	height_of
6	The swan is flying towards the north	disconnected (DC) (Use of topological relationship)	Flies_Over direction = north	direction

3.2 Representing Temporal Information

The general theme of temporal knowledge is an AI topic. The standard textbook by Russel and Norvig (2003) refers to temporal facts as fluent which represent instances of relations whose validity is a function of time. There are different approaches to translate this notion of fluents into the Semantic Web world.

The earliest approach recommended by the W3C is event entities which is having starting and ending time (Bob Lewis, 2007). **Figure 3** represents the method of organizing the temporal relationship using an event.

The following queries can be easily answered by the ontology

1. The horse image taken from 1-2-2013 to 10-2-2013.
2. Find the images of swan in water at early dawn.

The following sections describe the image ontology construction process using the spatiotemporal relationship and image retrieval using the SPARQL query.

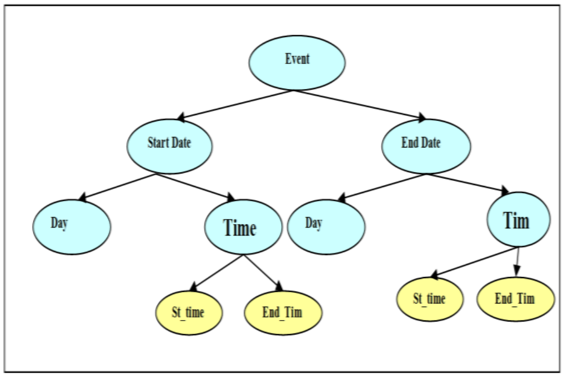

Figure 3. Temporal Relationship.

4. Developing an Ontology

The process of developing ontology is called ontologization. The goal of ontologization is to construct an information structure with only the necessary information in a compact form where all intended user groups can find every bit of information as quickly and as easily as possible. The ontologization is similar to a software development in general (Ayesha Banu et al. 2010). The first stage in developing ontology is requirement analysis. The languages and tools are selected for ontology development depending on the requirements. The ontologization needs the following steps.

1. Selection of Domain and Scope
2. Considering Reuse
3. Finding out Important Terms
4. Defining Properties of Classes and Constraints
5. Defining Classes and Class Hierarchy
6. Creating Instances of Classes

4.1 Selection of Domain and Scope

Ontology is a knowledge representation method. But it is used for image representation and retrieval. Hence the image is represented in a machine understandable manner, this leads to retrieval task easier. If the spatiotemporal data are added as part of the ontology, the image can be retrieved in a context sensitive manner. Hence, it leads to reduce the semantic gap. The ontology is designed with the intention of knowledge sharing, knowledge reuse and interoperability (Breitman, 2007).

4.2 Considering Reuse

Ontologies are usually constructed by a domain expert, someone who has mastered over the specific content of a domain (Brewster, 2007). It can be reused by means of integration. Ontologies should have fluid boundaries and be readily capable of growth and modification and easily scaled to a wider domain and adapt it to new requirements.

4.3 Finding out Important Terms

The terms used in ontology are domain, concept, object, constraint rules and relationships. The three types of relationships are expressed as shown in **Table II**. A spatial index is a special data structure that organizes information about the object in space based on their location so that spatial queries can be answered efficiently (Kristına Lidayova et al., 2012).

Table II. Various types of relationship

GENERAL RELATIONSHIP (GR)	SPATIAL RELATIONSHIP (SR)		TEMPORAL RELATIONSHIP (TR)
1. type of image 2. Creator 3. Theme 4. has legs 5. has wheels	1. Meets or Touches 2. Disconnected or Equals or Overlaps	3. CoveredBy or Inside 4. Latitude 5. Longitude	1. Actual date 2. Actual time 3. Added date 4. Added time

The spatial index is created by using the cognitive spatial relationship. The temporal data are easily conceptualized than spatial data, because time is merely an individual dimension. If the images are stored along with temporal information, it is very easy to retrieve the image using temporal queries.

4.4 Defining Properties of Classes and Constraints

Properties are attributes of the object in the ontology. Properties are having a binary relationship with individuals. They are used to link two individuals together and used to create a relationship between objects or classes. The set notations are used in defining the constraints. The scope is search space is controlled. There are two main types of properties.

1. Object properties
2. Data type properties

4.4.1 Object Properties

Object properties link two individuals together and present relationships.

Example

1. The cow eats plants - GR
2. The Sky is covered by birds - SR

This is used to link two individuals together. Relationships may be 0..n or n..m. The relationships between the classes are created by using properties. The **Figure 4** and **Figure 5** shows the assignment of the general properties and spatial properties between the classes.

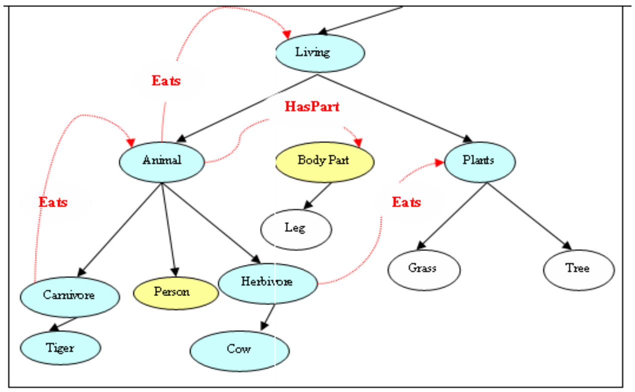

Figure 4. Creating a relationship between classes

4.4.2 Data type Properties

Data type properties are used to give value for the relations.

Example

1. The photo was taken on 20-04-2013 - TR
2. The photo was taken at 12 PM - TR

The relationship gives the context sensitive information in the retrieval of the images. Hence, the well established relationship in image representation provides more relevant data. The conventional search engine does not maintain the relationship among the data. Hence, it gives poor precision and recall value.

4.5 Defining Classes and Class Hierarchy

The ontology is constructed for representing the natural image domain. The most important classes are Animal, Bird, Person, River etc. A class may have subclasses. The class hierarchy is generated using the relationship exist between the classes. Classes are organized into a class and a subclass hierarchy known as taxonomy. This provides a mechanism for consumption reasoning and inheritance of properties.

4.5.1 Classes Hierarchy

Classes are a concrete representation of concepts. For examples, in the world of vehicle have the classes like car, motorcycle etc. The semantic relationship is created between classes and instances. The relationship specified in Table II is used for creating properties. Usually the ontology provides a multi layer tree structure hierarchy for description of contents. This enables machines to identify the content descriptions from human conceptual description. The quality of the retrieved results depends on the amount and consistency of the metadata associated with each image.

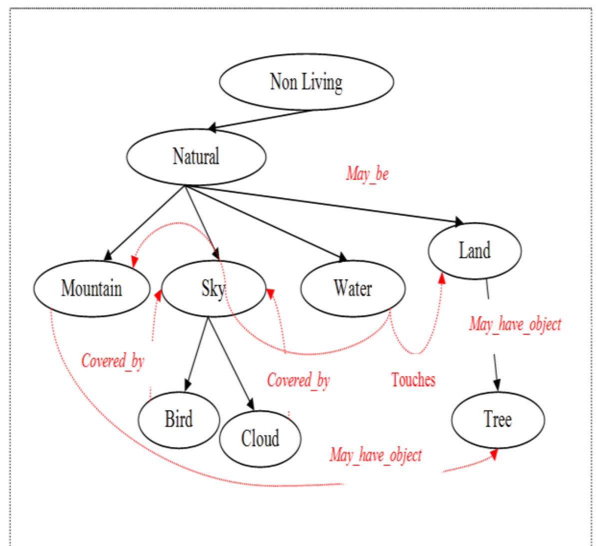

Figure 5 Connecting classes using spatial properties

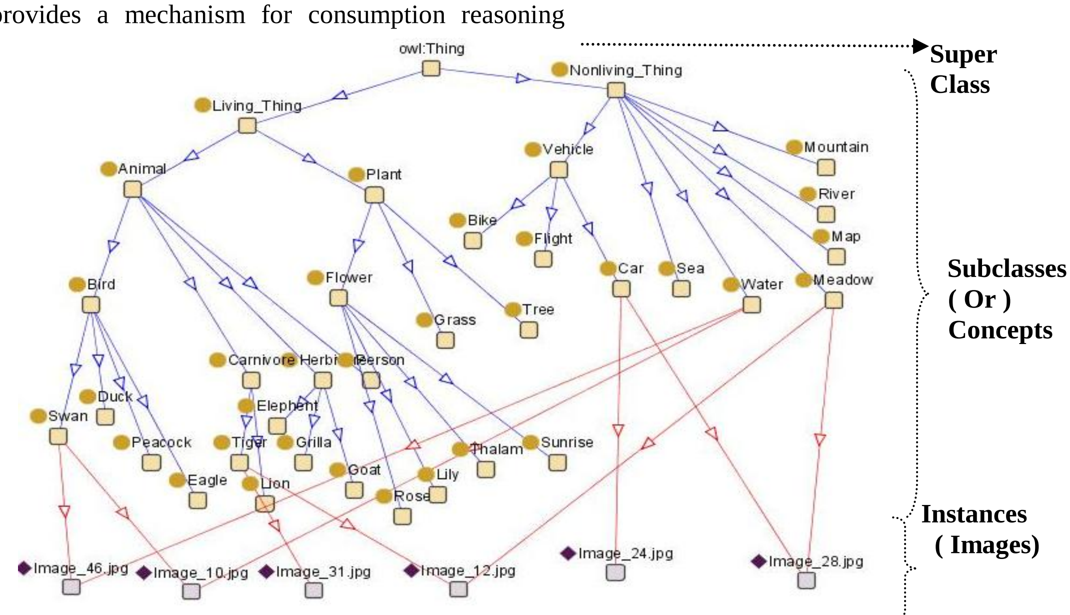

Figure 6 Structure of Class and Instances

The semantic relationship is created between classes and instances. For example, the carnivores cannot eat plants. The pet animals should not kill humans, all carnivores are dangerous. A cat can eat vegetable and non vegetables. Some deers are having white dots. The wheel is part of the car, etc. Usually the ontology provides a multi-layer tree structure hierarchy for description of contents. This enables machines to identify the content descriptions from human conceptual description. The quality of the retrieved results depends on the amount, quality and consistency of the metadata associated with each image (Kristina Lidayova, 2012).

4.5.2 Textual Descriptions

Text descriptor is purely based on text and it is used to encapsulate high level narrative image description. Every image is associated with its domain knowledge in the ontology. That is why the ontology works better than a single keyword on capturing semantic interpretations from a different context. The semantic relationships have been generated to connect different concepts. The general descriptors are Name, Theme, etc. The spatial descriptors are is_covered _by, meets etc., and the temporal descriptors are time and date is used as part of the ontology. The class and relationship specification are used in image extraction (Magesh and Thangaraj, 2011). The reasoner plays crucial role in identification of image using properties.

5. Image Annotation

Annotation is a process that facilitates descriptions of images. The annotation is decomposed into image annotation, image property annotation and concept annotation. For example, if the Elephant image is having forest in the background, the forest is linked to image by means of assertion property. So that the image will not get wiped out from searching for one of the property. The other values are added by means of data type properties and object properties. The properties are is_created_by, having_theme_of, has_place and has_Time. The semantic annotations will allow structural and semantic definitions of image documents. It provides completely new possibilities for intelligent search instead of keyword matching, query answering instead of information retrieval and document exchange between departments via XSL translations (interoperability). The Internet aids users in order to find information more easily, rapidly and at a lower cost of retrieval. However, human users usefully retrieve images at higher levels of semantics but this is still far from being achieved in practice (Wang et al.., 2008).

5.1 Text Based Image Annotation using ICONCLASS

The ICONCLASS is a tool used in high level image annotation and it is practiced in determining the general name of an object present in the picture. It

4.6 Create Instances of Classes

Instances are the basic, "ground level" components of an ontology. The individuals may include concrete objects such as people, animals, birds, plant, automobiles and planets as well as abstract individuals such as numbers and words. Individual objects that belong to a class are referred to as instances of the class. The individuals are created with respect to class and their respective data property and object property values are filled. The domain knowledge can be extended to cover more slots. Here for the swan image, assertion property is used to link swan with classes like River, Water, etc. So, it will not get wiped out from searching for one of these things. The high level narrative information of image descriptions from external data source is collected and encapsulated into classes and instances. **Figure 6** shows the class hierarchy and instances of ontology. It is natural that one image belongs to multiple classes since image semantics is represented by both multiple semantic entities contained in the image and the relationships between them, causing the actual classes to overlap in the feature space. The relationship between the classes is also given by means of object properties. The ontology structure is enriched by using more properties. This will lead to retrieve the most relevant images (improved precision) and all the relevant images (improved recall) in the image retrieval.

contains over 28 000 definitions organized in a hierarchical structure. It is a very detailed ontology for iconographic research and the documentation of images. It is used to index the iconographic contents of works of art, reproductions, literature, etc. The other important aspects of associating textual information with images are annotation and classification. In annotation, keywords or detailed text descriptions are associated with an image, whereas in categorization, each image is assigned to one of a number of predefined categories.

The ICONCLASS is used in extracting the various objects present in the image. The spatial relationships are given by using the objects. It is a semiautomatic process. The **Figure 7.a** gives the whole image annotation—the listed keywords are associated with the image (dog, grass, brick surface) and **Figure 7.b** gives Segmentation and annotation—keywords are associated with each region of the segmentation. Keywords describing the whole image can also be used. Allan Hanbury (2008) describing the various annotation method for describing the image and finally choosing the keyword based annotation as the best method. Each image is annotated with a list of keywords associated with it. There are two possibilities for choosing the keywords

- The annotator can use arbitrary keywords as required.

- The annotator is restricted to using a pre-defined list of keywords (a controlled vocabulary).

This information can be provided at two levels of specificity:

1. A list of keywords associated with the complete image, listing what is in the image (see **Figure 7a** for an example).

2. A segmentation of the image along with keywords associated with each region of the segmentation. The text descriptions generated by the ICONCLASS is annotated as part of the ontology. The object in the image is represented by means of cognitive spatial relationship since it is having minimum set properties which are enough to denote the natural images.

5.2 Object extraction using ICONCLASS

The main limitation of the ICONCLASS is that its scope is limited. It is able to generate the text description for 28 000 real world objects. It is enough to understand the general images. **Figure 7** shows the usage of ICONCLASS for dog image. The **Table III** gives the spatial representation format of **Figure 7**.

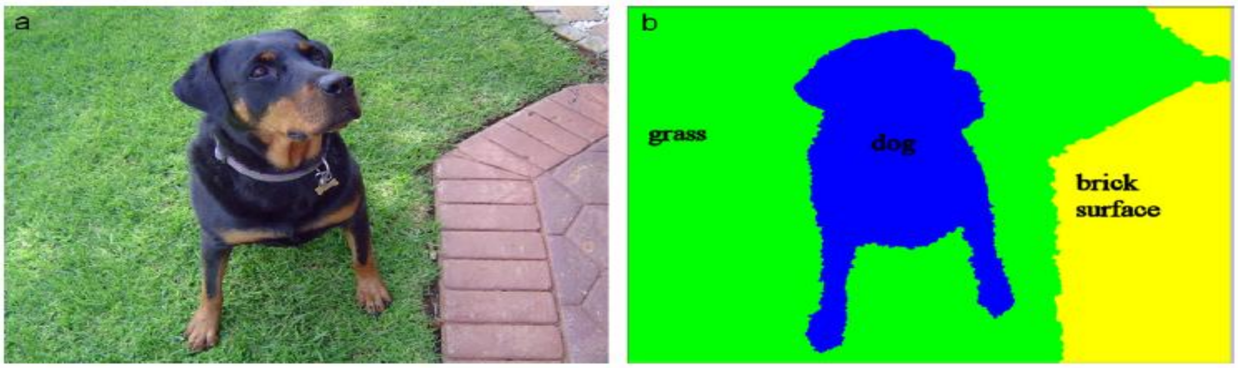

Figure 7 Image annotation using ICONCLASS

Table III - High Level feature representation using ontology

S.No	Features			Representation
	Method	Name	Type	
1	General	Name of Image	Data type	Dog1.jpg
2		Object	Data type	Dog,Brick Surface ,Grass
3		Is_created_by	Object type	Mr.M.Aswinth
4	Spatial	Has_Place	Data type	Botanical Garden, Bangalore
5		Latitude	Data type	13.22
6		Longitude	Data type	12.33
7		Covered_by	Object type	Grass
8	Temporal	Has_date	Data type	01-02-2013
9		Has_time	Data type	10.30 AM

A knowledge based model is a potential solution to resolve this issue. A Knowledge Base is defined as capturing and organizing the expertise and experience of a collective. The ontologies are used to symbolize the high level knowledge from the image (James Z. Wang , 2008). The **Table IV** represents the expressions for various types of objects using cognitive spatial relationships. These are annotated to the ontology by using properties.

Table IV – Spatial relationship for the objects in the image

S.No	The spatial relationship created for **Fig** 7
1	The Dog is covered by Grass
2	The Grass touches the brick surface
3	The Dog is near to the brick surface

6. Ontology Based Image Retrieval

The OBIR is used to provide only the relevant image to the user and gives better precision (Ayesha Banu, 2011). The main advantage of this study is to take the image with respect to the human context level. The SPARQL obtains a higher precision and recall than the text based approach (Magesh and Thangaraj, 2013). The semantic model improves the retrieval performance significantly by adding the above relationships. Twenty five sample queries were run against the image ontology created with 2000 images and its level is 11. It includes 75 classes, 10 general properties, 9 spatial properties and 4 temporal properties. The 2000 images are taken for the analysis and 25 relevant images are present in each category. **Table V** shows the precision and recall value for various SPARQL queries.

7. Experimental Set Up

The image ontology is created for 2000 images. The OWL file consists of classes, properties and instances as images. The meta data description is given by using XML, RDF and RDFS. The ontology is questioned by using various quires as follows.

1. One Word and Two Word query
2. The query uses Noun and Preposition
3. The query uses Noun and Preposition as spatial relation
4. The query uses Noun and Preposition as temporal relation
5. The query uses Noun and Preposition by using spatiotemporal relation

1. One Word and Two Word query

Query 1: Find the picture of the Swan

SPARQL FORM:

```
SELECT ?X
WHERE { ?X rdf:type :Swan }
```

Answer

- Swan1
- Swan2

Query 2 : Find images of Horse and Grass.

SPARQL FORM:

```
SELECT ?X ?Y
WHERE { ?X rdf:type :Horse .
        ?Y rdf:type :Grass }
```

Answer

- Horse1
- Grass

2. The query uses Noun and Preposition

Query 3: Find the birds having white color

SPARQL FORM:

```
SELECT ?Y ?X
WHERE { ?X rdfs:subClassOf :Bird .
        ?Y :Color "White" }
```

Answer

- Swan1
- Duck1

3. The query uses Noun and Preposition as spatial relation

Query 4 : Find the Horse surrounded by Grass**.**

SPARQL FORM:

```
SELECT ?X
WHERE { ?X rdf:type :Horse .
        ?X:is_covered_by "Grass" }
```

Answer

- Horse1
- Horse5

Query 5 : Find the images of Grass connected with the Tree.

SPARQL FORM:

```
SELECT ?X
WHERE { ?X rdf:type :Tree .
        ?X :is_meet "Grass" }
```

Answer

- Tree4
- Tree6

4. The query uses Noun and Preposition as temporal Relation

Query 6 : Find the Horse image taken on 1-2-2013.

SPARQL FORM:

```
SELECT ?X
WHERE { ?X :Date ?Date ;
FILTER regex(str(?Date), "2013-2-1") }
```

Answer:

- Pic4
- Pic5

5. The query uses Noun and Preposition by using Spatiotemporal relation

Query 7 : Find the Dog images connected with the Tree taken on 01-02-2013 at 10 AM.

SPARQL FORM:

```
SELECT ?X
WHERE { ?X rdf:type :Tree .
        ?X :meets "Grass" .
 FILTER regex(str(?Date), "2013-2-1"). ||
 FILTER regex(str(?Time), "10") }
```

Answer

- Dog2
- Dog3

The main advantage of this work is to take the image with respect to the human context. The SPARQL obtains a higher precision and recall than the text based approach. The semantic model improves the retrieval performance significantly by adding the above relationships. **Table V** gives the precision and recall value for spatial queries (Type 3). Similarly, the precision and recall value for other types of queries are found and precision and recall graph is drawn as shown in **Figure 8.**

Table V . The Precision Vs Recall value for spatial data as input

S. No	Input Query	Precision	Recall
1	The animal eats Plants	0.55	0.70
2	The swan swimming in the river	0.73	0.68
3	The swan in lake	1	0.60
4	A monkey sitting on a tree	0.65	0.68
5	The animal eats plants and animal	0.05	0.95
6	Birds living in water and land	0.32	0.90
7	The dog walking in a grass	0.82	0.41
8	The swan is flying over the river	0.62	0.82

It is observed that the ontology based retrieval out performs the keyword based techniques. The present search engines consider the keyword as an individual atomic unit. But the semantic concept creates a relationship between the keywords. Hence, the more relevancies can be obtained when compared to traditional search methods. The retrieval effectiveness is evaluated by using the classic information retrieval measures—precision and recall. The graph in **Figure 8** shows the efficiency of the method. The SPARQL retrieval increases the recall value of the image set.

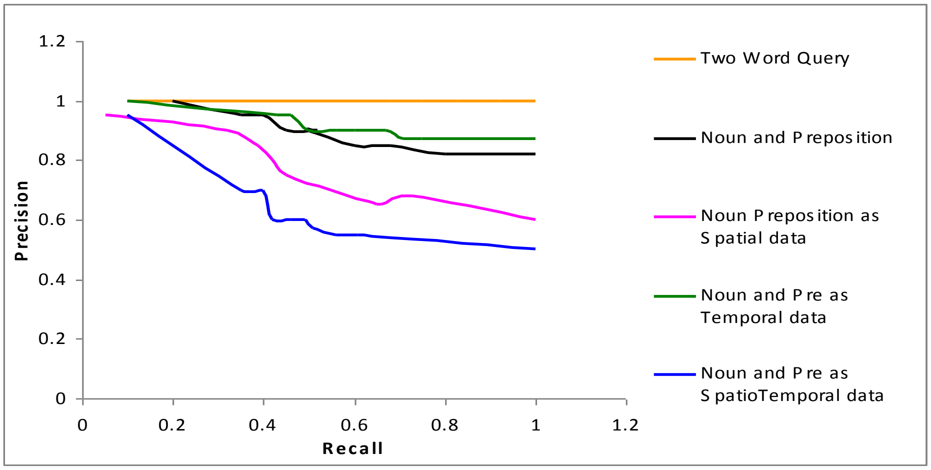

Figure 8. Precision Vs Recall graph for spatiotemporal queries

8. Conclusion

The proposed method integrates the image data with spatial and temporal dimension of data. The image ontology is constructed using spatial and temporal relationship using protege. The image is annotated by using spatial relationship like connected, disconnected and covered_by and temporal relationship like date and time. The tool ICONCLASS is used for taking the spatial properties. The other spatial information like latitude and longitude and temporal information like time are captured from digital camera and stored as the part of the ontology. The image is extracted from ontology using SPARQL query language. The more relevant images are extracted by means of spatial and temporal properties. Hence, the semantic gap is reduced by the use of spatiotemporal relationship for the image retrieval from ontological structure and it has been proved by using precision and recall graph.

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7/9/2013