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Performance assessment of a semantic information retrieval system using stagnant and active images

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Videos, images, graphics and text are the main multimedia data types. Generally, one document includes two or more data types because each data type enriches the meaning of document. For this reason, the documents become more complex for querying when compared with only text querying. To overcome this difficulty, some new information retrieval systems have been developed. In this study, an object action concept (OAC) based semantic information retrieval system for text and image data by using Fuzzy ontology was considered. Assessment of the performance of the retrieval systems is highly important. The purpose of this study is to assess the performance of an object action concept based semantic information retrieval system when using stagnant and active images. When considering the precision recall, precision and r_{norm} parameters, it is clear that the performance of the system for the stagnant images is higher than that for the active images.

Key words: Fuzzy domain ontology, image and text retrieval, semantic querying.

INTRODUCTION

Depending on the rapid increase in the documents in digital medium, a growing demand for efficient methods to retrieve semantic information and to extract knowledge from multimedia content have been observed. Main multimedia data types can be classified as videos, images, text and graphics. All these data types can be used in same documents because the usage purposes of these multimedia data types are different. In other words, each data type presents different information in different style. When they are used together in a document, the meaning of the document can be enriched. However, retrieving the information from these complex documents may be difficult. When compared with the other multimedia data types, images are the most frequently used multimedia data types. Images are generally used in a document with textual part, because images in a document present visual representation of informations obtained from various sources. Consequently, use of images in a document may result in increase of quality, richness and explanatory power of the document presented. However, traditional search engines are mainly based on text. It is possible to say that using only text to search the web is not always sufficient because most of the web pages consist of not only textual part but also some images. For this reason, development of some new information retrieval systems is indispenable. Considering these reasons, Sezer (2006) and Sezer et al. (2006) developed a semantic information retrieval system (OAC based semantic information retrieval system – OAC-SIRS) for text and image data by using Fuzzy ontology, because using this complementary relationship in queries increases the reliability of the results. In the first stage of the system proposed by Sezer (2006) and Sezer et al. (2006), images from visual data are selected and then, text and images are used together, while indexing and querying. The basic features of the system suggested by Sezer (2006) are; the ability for semantic querying of images and texts by the same query sentence at the same time, and the ability of enclosing all semantic levels (‘object, action, and concept’) by using Fuzzy domain ontology. These features of the system provide important advantages when querrying images and texts together. In OAC-SIRS proposed by Sezer et al. (2006), the document is indexed or queried by not only using textual parts or images but also both of them. In this paper, the basic principles of OAC-SIRS are given and its retrieval performance is discussed by applying two different domains. The domains selected are; medical and sports because one of these domains includes stagnant images while the other contains active images.

PREVIOUS STUDIES

In the literature, there are some previous studies about Fuzzy domain ontology and semantic information retrieval. Some of the related studies in literature are given briefly in this section. Widyantoro and Yen (2001) propose an automatic construction of Fuzzy domain ontology consisting of broader and narrower term relationships by using term frequencies, and Kim (2005) introduces the design and implementation of an ontology based web retrieval-system by using an ontology that are previously loaded into database. Lagoze and Hunter (2001) describe the ABC metadata model collaborated with CIMI museums and libraries. Based on this model, they are able to build a RDF metadata repository. Sugumaran and Storey (2002) suggest a methodology for creating and managing domain ontologies by presenting an architecture for an ontology management system. Reinberger et al. (2004) obtain some semantic relations from text by an unsupervised way and use outputs as preprocessed material for ontology construction. Parry (2004) presents a discussion on the ontology Fuzzification, by both analysis of a corpus of documents and the use of a relevance feedback mechanism. Vallet et al. (2005) propose a model for the exploitation of ontology to improve search over large document repositories. Song et al. (2005) describe an ontology-based information retrieval model for the Semantic Web by using OWL-Lite as standard ontology language. Chang-Shing and Zhi-Wei (2005) present a Fuzzy ontology and its application to news summarization. In the study published by Chang-Shing and Zhi-Wei (2005), ontology is constructed in crisp form, while its uncertainty problem is solved by Fuzzy inference mechanism. Lee et al. (2007) suggest a novel episode-based ontology construction mechanism to extract domain ontology from unstructured text documents. Hernandez et al. (2007) apply semantic indexing on documents considering the their context representation and the user searches the information by browsing the ontologies. Diaz-Galiano et al. (2009) describe the effect of query expansion on retrieval by using medical ontology. Bhatt et al. (2009) propose the system by combining the use of ontology driven annotations on existing documents and the application of a novel sub-ontology extraction methodology to improve the effectiveness of information retrieval for the specific medical domain.

In the present study, ontology structure in text data during indexing and querying processes is employed. Additionally, to achieve exploration of semantic features of images and text, thesame ontology should be used. For this reason, ontology based image retrieval systems are considered. Schreiber et al. (2001) investigated the use of background knowledge contained in the ontology to index and to search collection of photographs. They develop an annotation strategy to help in the expression of annotations and search images. Hu et al. (2003) present a system to formally annotate medical images captured for diagnosis and management of breast cancer. Hyvönen et al. (2003) propose a system namely Ontogator. Ontogator employs RDF based ontology used in annotation and ontology development and annotation are made manually. Schober et al. (2004) suggest a supervised learning system OntoPic which is based on the well-known ontologies coded in DAML+OIL. Domain knowledge is used for better object recognition in OntoPic. Doulaverakis et al. (2005) develop an ontology based representation in order to provide enhanced unified access to heterogeneous distributed cultural heritage digital databases. For this purpose, CIDOC-CRM ontology is developed by an interdisciplinary working group manually, and images are also assigned to ontology manually. Zinger et al. (2005) describe a large scale image ontology using WordNet. For this purpose, the branches of WordNet leading to portrayable objects are only used by Zinger et al. (2005). Khan and Wang (2006) combine various different models to link visual tokens with keywords based on the clustering results of K-means algorithm with weighted feature selection and without feature selection. Buitelaar et al. (2006) discuss the current status of Smart Web Ontology-Based Annotation (SOBA) component, populating a knowledgebase by information extracted from soccer match reports as found on the web automatically. The extracted information is defined with respect to an underlying ontology. Wei and Barnaghi (2007) employ the semantic web technologies in medical image search and retrieval processes by considering the medical image ontology that consist of three main parts: Media dependent information, intrinsic features of image and extra information for special requirements. Lacoste et al. (2007) propose a medical concepts from the UMLS to allows working, at a higher semantic level. To bridge the semantic gap between low-level images features and the semantic UMLS concepts, Lacoste et al. (2007) suggest a structured learning framework based on support vector machines. Hudelot et al. (2008) propose an ontology of spatial relations along with its integration with existing domain ontologies. Allampalli-Nagaraj and Bichindaritz (2009) present some sophisticated image-processing techniques to automatically extract image content information into MPEG-7 format, and associate them to the existing domain ontologies developed by experts to fill the gap between low-level features and high-level semantics. In OAC-SIRS proposed by Sezer (2006), semantic features of the documents are produced by the combination of semantic features of images and textual part to reflect the complementary relationship between image and text. In other words, two different data type are employed at the same time. OAC Model is used to produce same style semantic features for images and

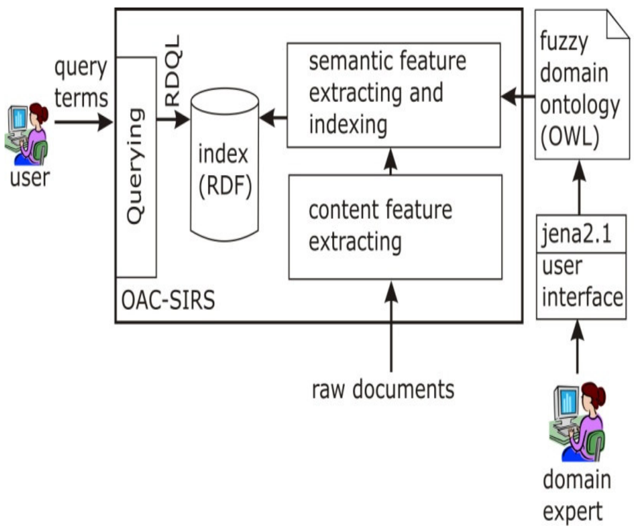

Figure 1. OAC-SIRS structure with all inputs and outputs.

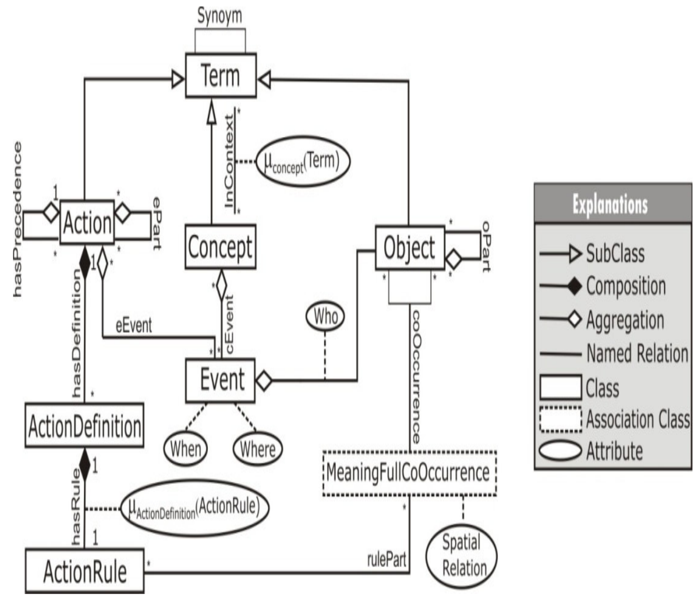

Figure 2. Schematic representation of the OAC Model (after Sezer, 2006).

texts by taking into consideration, the requirement about combination of features to set whole document features. Based on this approach, OAC-SIRS can be regarded to be different from the studies mentioned in this section.

THE BASIC FEATURES OF OAC-SIRS

In this section, the basic features of OAC-SIRS are given only, because the details of OAC-SIRS can be found in Sezer (2006) and Sezer et al. (2006) studies. OAC-SIRS can be divided into four modules owing to their functionalities. These modules can be grouped as ontology management, extraction of content features, extraction and interpretation of semantic features, and querying. All of them and their relations can be seen in Figure 1. User can model his/her domain by employing OAC Model approach manually, using the ontology editor and then then store. Then, user submits raw documents to the content feature extraction module and annotates region of images manually, but other features are extracted automatically. In subsequent stage, user selects the documents and domain ontology to be associated. After domain ontology based semantic feature extraction and automatic indexing, all results are stored for querying. User can query the system by using query module with the query sentence including domain terms and logical operators. In OAC-SIRS, domain ontology is stored by using Web Ontology Language (OWL) (http://www.w3.org/standards/techs/owl). Semantic features are stored by using Resource Description Framework (RDF) (http://www.w3.org/standards/techs/rdf), and the RDF Data Query Language (RDQL) (http://www.w3.org/Submission/RDQL/) is then used in querying.

Berners-Lee et al. (2001) reported that the semantic web has been extending on current web at the point of content representation with the machine accessing/sharing/processing abilities. Ontology is the key technology for Semantic Web, and the domain ontology can be defined as conceptual model representation of any domain. The mission of the ontology in the semantic web is to provide knowledge to machines for processing. To achieve sharable ontologies, its representation language plays an important role. Domain ontology requires two main stages such as domain modeling for ontology development, and association of entities with ontology. OAC Model proposed by Sezer (2006) presents an approach to model the domain, considering Fuzzy's approach. Zadeh (1965) proposed the Fuzzy set theory and its application areas, and developments of Fuzzy systems have increased gradually. The domain ontology derived from OAC Model is a Fuzzy ontology. It has entities and relations, basically. Fuzzy ontology is a conversion of ontological relations from crisp logic to fuzzy logic (Sezer, 2006). OAC Model does not contain a specific entity or relation for any domain as can be seen in Figure 2 (Sezer et al., 2006). OAC Model is not domain dependent, but the ontologies derived from OAC model are domain dependent, certainly. Although image and text are the focused of indexing and querying, OAC Model is designed mainly for semantic interpretations of image. When the OAC Model was designed by Sezer et al. (2006), three questions had to be kept in mind: "what are there in the image?", "what is happening in the image?" and "what does it mean?". As can be understood from the last two questions, practically, OAC Model had to be considered as Fuzzy. In addition, OAC Model

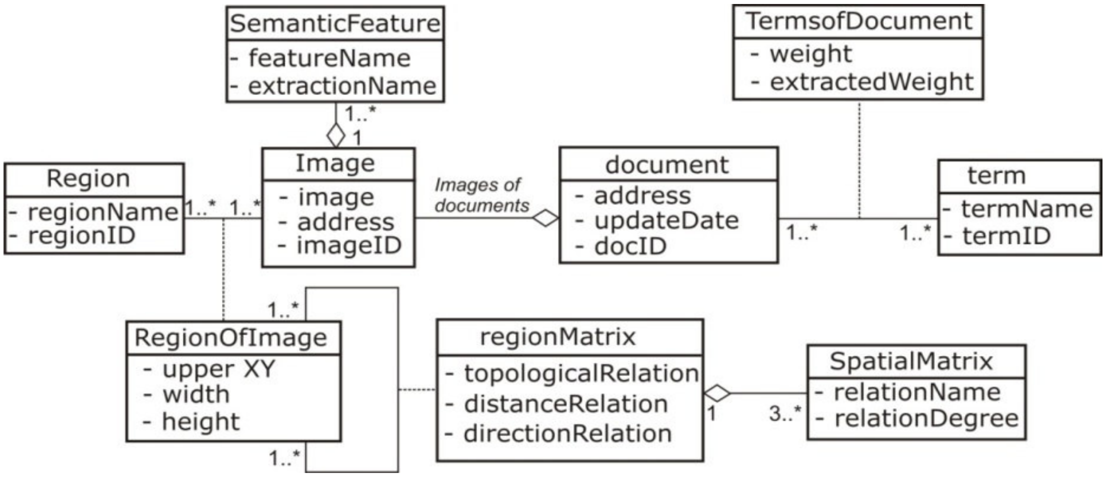

Figure 3. Meta model of the document (Sezer, 2006).

serves as textual data as well, because interpretations of image employ domain terms and relations which are useful for semantic interpretations of texts. For domain ontology derivation from OAC Model, an application is developed by using Java Technologies to enable user to manage the domain ontology, based on OAC Model. In fact, ontology management library called Jena Library Software (http://jena.sourceforge.net) developed by HP Labs using Java, is used as encapsulated from the user.

It is evident that there are major differences between content features of images and text in that two different processes are employed for content feature extraction by Sezer et al. (2006). For textual part of document, Vector Space Model (VSM) (Salton et al., 1975), is used to produce term-document matrix. Weights of terms are calculated in this stage to reflect the frequency of the term in the document and frequency of the term in the collection after picking up the stop words from the collection. They are re-calculated in the phase of semantic indexing. Content feature of an image consists of region names and spatial relation of regions. Regions are annotated manually while spatial relations are calculated automatically. Thus, output of this process for each image is region-region matrix, reflecting spatial relations between them. Spatial relations are in accordance with definitions in OAC Model. As a result, each spatial relation has three participants such as directional, topological and distance.

Semantic feature of document is produced by application of ontological relations and definitions to the content features. Expected outputs from this process are terms and weights. For semantic features of the textual part, Equation 1 is employed by Sezer (2006). Lets assume that "i" is the number of term, "m" is the number of document, "W_{im}" is the new weight of i^{th} term in m^{th} document reflecting semantic relations obtained from domain ontology, "w_{im}"is the weight of i^{th} term in m^{th} document calculated in content feature extraction process, "t_p" is another term, 'Ontological relation' (t_i,t_p) is a binary-valued relation. As can be understood form Equation 1, co-occurrences of the terms related to i^{th} term in domain ontology, provide an increase in "w_{im}" value. Thus, even if "w_{im}" is zero, "W_{im}" can be greater than zero, and this situation corresponds to new semantic feature extracted from the textual part. Consequently, expansions are performed on the term list of the document. For this reason, query is not required to expand any more (Sezer et al., 2006):

$$W_{im}=w_{im}+\sum_{p=o}^{\text{number of terms}}(w_{pm}\ p!=i\ \&\&\ \mathit{OntologicalRelation}(t_i,t_p)!=0)\ /\ \text{number of terms} \quad (1)$$

For semantic feature extraction of images, region names and region – region matrix of each image are applied to the definitions of 'Action' and 'Concept' individuals in the domain ontology. Actually, in the first stage of the association, the image with domain ontology is mapping of region names with 'Object' individuals in the ontology. After this process, 'Action' individuals are mapped together with region-region matrix by using 'ActionDefinition' and 'ActionRule' individuals. In fact, 'ActionRule' individual has thesame style with region-region matrix. Additionally, it has Boolean operators used to connect rules. In other words, 'ActionRule' has the required 'Objects' and spatial relations needed to deduce that 'Action' and region-region matrix has regions and spatial relations that are extracted from the image by Fuzzy. Consequently, a Fuzzy testing between matrix and 'ActionRules' is required (Sezer et al., 2006). Meta model of the document including all extracted semantic and content features is given in Figure 3 (Sezer, 2006). Meta model of the document is represented with RDF, and accordingly, it can be queried with RDQL. In fact, user submits domain terms with the Boolean operators if they are needed, and RDQL statement is produced automatically. Meta model keeps the features extracted from textual parts and images, separately. Accordingly, user can query them separately (Figure 3). If user wants to query the whole document, union of semantic features coming from texts and images are used.

EXPERIMENTS AND COMPARISON

In OAC Model, to decribe images by using objects, namely regions and their layouts, is the fundamental approach. According to this approach, system should be tested on stagnant and active images, seperately, and compared to clarify its performance on semantic indexing and retrieval. Sezer et al. (2006) presents the OAC-SIRS performance on active images, but not on stagnant images. Based on experiments of this study, images from medical domain is used, and OAC-SIRS is tested on this domain. The results obtained from medical domain are compared with results obtained from sports domain presented by Sezer et al. (2006). As observed, while medical domain corresponds to case of stagnant images, sports domain represents case of active images. To compare the results, three well-known information retrieval parameters (precision, recall and r_{norm}) are employed.

In medical domain, upper human body subdomain is selected, and document collection is produced manually. A total of 40 documents were produced manually with the help of a medical doctor (Assist. Prof. Dr. Kemal Arda from Ridvan Ege Hospital, Ankara, Turkey). In fact, Computer Tomograph (CT) images are used, and textual data are inserted in the documents, manually. Especially, names of structures, organs, part of organs and systems are considered in the textual part. A total of 10 queries are employed. Eight of them correspond to 'Action' level (Query1: "lung", Query2: "whole liver", Query3: "kidney", Query4: "whole stomach", Query5: "digestion system", Query6: "right kidney", Query7: "whole pancreas", Query8: "left kidney") and two of them corresspond to 'Concept' Level (Query 9: "thorax", Query10: "abdomen"). The reason for this type of organisation is to be close with the experiments presented by Sezer et al. (2006). Concept terms are not used in textual part directly to observe semantic interpretation performance on images. It is known that the common content features of documents and queries have a great influence on retrieval performance. As a result of this, four type documents for each query such as "unrelated documents", "documents including related images", "documents including related text" and "documents including related images and texts" were produced to observe OAC-SIRS perfomance more accurately.

Sezer et al. (2006) use the volleyball sub domain in sport domain, and a total of15 web pages collected from the new sites in the Internet, related to "volleyball" domain, were included as documents. As stated by Sezer et al. (2006), a total of six queries are used and three of them correspond to 'Action' level (Query1:"spike", Query2:"service", Query3:"block"). The others correspond to 'Concept' level (Query4:"attack", Query5:"defense", Query6:"match").

When volleyball and upper human body sub domain were compared, it was observed that they have highly different image sources. In volleyball domain, most of the images include the instant of the movement. As a result, a movement can have more than one different but close definition. In addition, the position of the camera capturing the image affects the spatial relations of the objects on the image, and all these realities affect the degree of fuzziness during image semantic interpretation phase. In the upper human body domain, there are stable spatial relations between organs and structure. Moreover, position of the camera is constant. Consequently, description of an action in this domain can be performed, more precisely, but not in a crisp way. In this study, same approach is employed along with that of Sezer et al. (2006) to make reasonable comparison:

1. Text querying with Apache Lucene (http://lucene.apache.org/java/docs), a high performance, full-featured text search engine library.
2. Text querying with OAC-SIRS to explore the semantic interpretation ability of OAC Model for text.
3. Image and text are queried by using OAC-SIRS to explore the influence of semantic relations between images and texts, and semantic interpretation ability of OAC Model for images.

In Figure 4, recall, precision and r_{norm} values of sports (volleyball) domain and medical (upper human body) domain are illustrated. The text based retrieval using OAC-SIRS in two domain, produces high recall values than the Lucene's system, because of the consideration of ontological relations, while weighing the term. Especially, if the document includes no common term with the query, Lucene's performance is dramatic, but OAC-SIRS achieve some good results (Figure 4) by the way of expanding semantic features of documents. When text and image retrival using OAC-SIRS is considered, it is evident that image semantics are inferred accurately, and they contribute the semantic features of the documents. As a result of this contribution, it has higher recall values than text-retrieval for each domain (Figure 4). When recall values of the two domains are compared; it is clear that semantics in upper human body domain images are inferred more succesfully. The reason for this difference is based on the OAC Model approach which describe an 'Action' ('Objects' and spatial relations are used). In an active image, spatial relations can change from one instant to another, and the instant of the motion

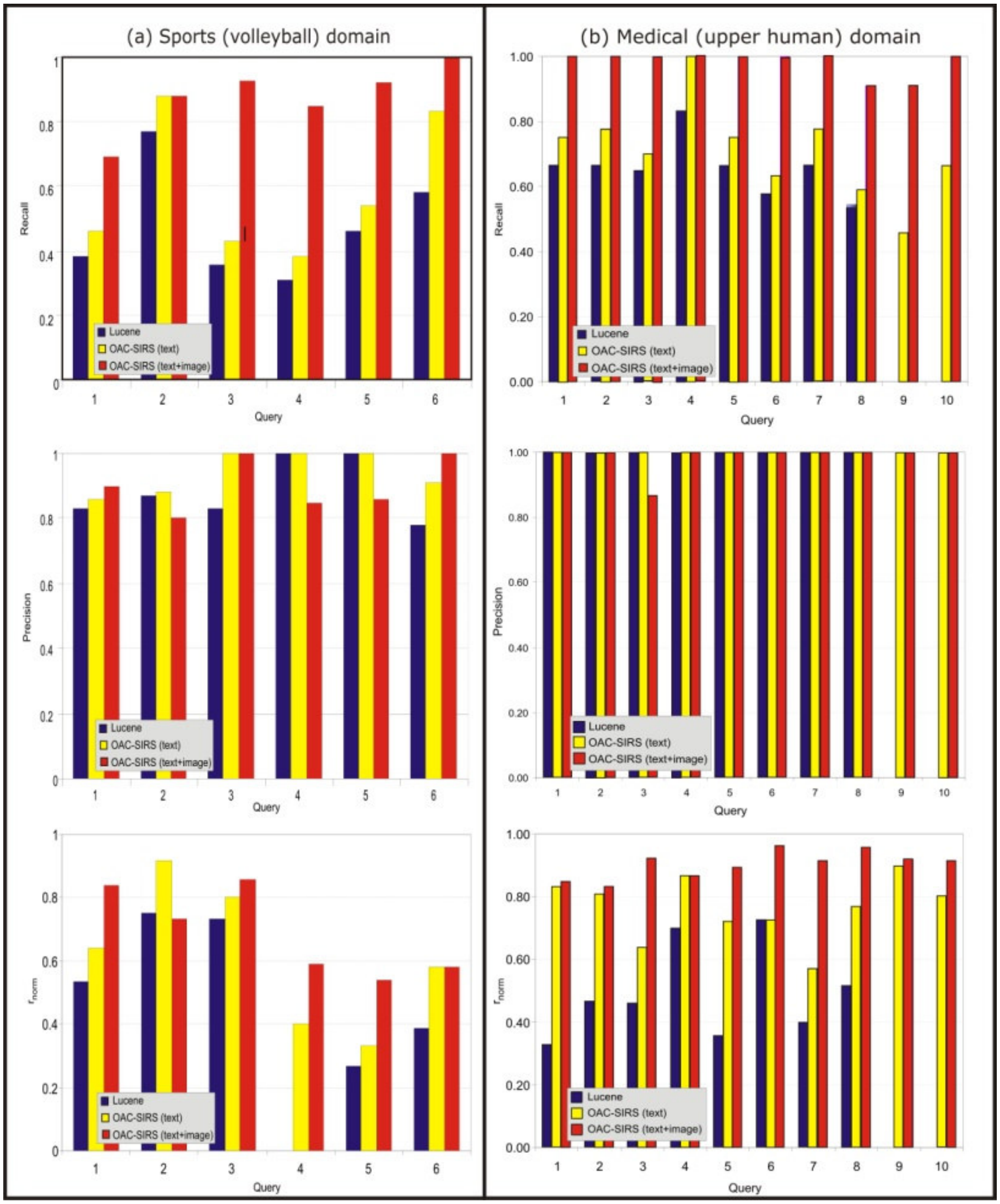

Figure 4. Graphs showing the values of recall, precision, and r_{norm} for sports domain (a) and medical domain (b).

captured by the camera affects the satisfaction degree of ‘Action’ description. One of these types of domain is volleyball domain and in contrast of sports domain, images of upper human body are stagnant. As a results, description quality of the ‘Actions’ in the domain ontology and the stationary spatial relations affects the inference reliability of them and this influence can be observed saliently in Figure 4.

Precision values of Lucenes based text retrieval is close, but lower than OAC-SIRS based text retrieval for two domains. The main reason for this situation is that document collections employed in the experiments are; close and small collections. In other words, there is no homonym problem, and limited number of terms are used. As a result, high precision values are achieved for all types of retrievals in general. However, precision values are meaningful to compare OAC-SIRS performance on semantic features of images. There are three points showing lower precision values than text retrieval for volleyball domain (Figure 4(a)). It is clear that irrelevant documents are retrieved because of errenous semantic feature extraction from images. This event occur only onece in upper human body domain (Figure 4(b)). The reason for this reduction is based on the nature of the stagnant and active images. As stated previously, statinary spatial relations in stagnant images provides high quality for 'Action' describtion and more reliability to infer 'Actions' from images.

r_{norm} shows the accuracy degree of retrieval output sorting. Text retrieval performance of the OAC-SIRS is higher than the Lucene's performance for two domains. The reason for this improvement stated by Sezer et al. (2006) is that when the query term placed in the textual part of the document has another ontological related terms with itself on the same document, weight of the term increases and the doucument becomes more related to the query. When image and text retrieval performances of the two domain is compared, there is better results in upper human body domain than volleyball domain. In volleyball domain, there is a point that causes the production of lower r_{norm} perfomance because of the errenous semantic feature extraction from active images. However, in the upper human body domain, semantic features of the stagnant images are extracted more accurately, and r_{norm} values shows an increase in the quality of retrival output sorting.

According to the obtained results from the experiments, semantic features of the images are not negligible for a document and especially, stagnant images have more positive contribution on the performance of retrieval than active images, because stagnant images are more suitable to OAC Model approach in the point of description clarity of 'Actions'. This situation can be seen clearly when graphics of the upper human body domain and volleyball domain are examined. Number of errenous semantic extractions from stagnant images is lower than that of active images. Finally, it is observed that precision and r_{norm} values increase. In addition, when precision and r_{norm} values are considered together, semantic features of the images have more positive contribution on retrieval performance than their negative contributions in general.

CONCLUSION

In this study, OAC Model proposed by Sezer (2006) and tested on sports domain (Sezer et al., 2006) is applied to the medical domain. The reason for the medical domain selection is that sport domains have the images of movement (including an instantaneous movement) namely active images. However, in medical domain, images include mostly, part of the body and they have no movement, in other words, they are stagnant. When OAC Model approach for semantic features extraction from image is considered, it is reqiured to test it on the stagnant images. As a result of the comparison between stagnant and active images of two different domains, stagnant images are more suitable to OAC Model approach than active images. In other words, stagnant images enable OAC-SIRS to achieve better retrieval performance than active images.

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