Ontology-Based Query Recommendation as a Support to Image Retrieval

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Abstract. Stock photo libraries are the most common means for publishers and advertisers to find images for their media. Searching for the perfect photo can be a time-consuming and frustrating task. This is because searching is often dependent on the descriptors or tags given to each photo by the editors and contributors to the library. The tagging process is subjective, further complicating the search process. We describe an algorithm that uses domain ontologies to improve the interactions with these libraries. Ontologies are used to expand query terms based on users' initial search queries. We present results that demonstrate that the use of ontologies greatly improves users ability to retrieve photos when undertaking a number of search tasks.

1 Introduction

Stock photo libraries, such as Alamy[1], offer online sources of images for media and advertising. Searching of these libraries is facilitated by keyword tagging. For this to be most effective, contributors must tag each of their images with a long list of annotation keywords. However, since contributors tend to have very large photo collections, manually tagging every photograph is a very time consuming, tedious and error prone task. To compound the problem, different people will often use different words to describe the same image. As a result, where images are not sufficiently marked-up, users will need to provide a large selection of search terms in order to find them. It can often be the case that users will have an idea of what they are searching for without knowing specifically what it is. This makes the searching process very difficult, especially in the case that the user is not experienced with search techniques. The use of ontology-based support tools can help to address these challenges and improve user interactions.

Ontologies are a way of describing concepts and their relationships within a specific domain. By creating an ontology of a domain it is possible to specify the concepts within it and how they relate to each other [1], e.g., both car and bus can be defined as types of land vehicle, which have a disjoint relationship, i.e., something cannot be both a car and a bus. We have developed ontologies to represent common search terms used in photo libraries. These ontologies are

[1] Alamy, http://www.alamy.com

used by a keyword-generation tool to expand a user's search keyword. This is achieved by finding which concepts in the ontology relate to a keyword and retrieving information about each of these concepts. The performance of an ontology-based search is compared to that of a standard search and shown to improve user performance in image retrieval for a set of predefined user tasks.

The remainder of the paper is arranged as follows. Related work is discussed in the Section 2. Section 3 describes the ontologies that were developed and the implementation of the keyword-generation tool. The evaluation methodology used is described in Section 4 and the results are discussed. Section 5 concludes the paper and discusses future work.

2 Background

Baeza-Yates et al., discuss the challenges involved in the process of using web search engines in order to find information [2]. They describe how users with the same aim may phrase their search queries differently and users are likely to repeatedly redefine their search query until they achieve satisfactory results. Users are described as possibly having little knowledge about the information they are searching for and sometimes not being certain about what it is they are specifically searching for. To address these challenges Baeza-Yates et al. propose a method for suggesting relevant queries to a user of a search engine. The method is based on a query clustering process which uses historical preferences of registered users so as to identify groups of semantically similar queries. Related queries are discovered and ranked according to a relevance criterion. The related queries displayed to a user can then be used in the search engine to redirect the search process.

There has been much research into using ontologies to improve image search and retrieval methodologies [3–8]. Hyvönen, et al., use ontologies to aid annotation, user search and browsing [5]. Their technique requires changes to the way the images need to be annotated and the way the users can find the images. While they make additional information available to the user, the interactions they perform with such an interface would change considerably compared to standard image search and annotation interfaces.

Schreiber et al., explore the use of ontologies to index and search collections of photographs [3]. They developed a tool for annotation and searching for specific images. Based on their evaluation of metadata standards, e.g., Dublin Core[2], they decided to define their own ontologies rather than re-use existing ones. They described the things that needed to be stated about a photograph as: subject matter, photograph feature, and medium feature. They focused on subject matter, using the domain of Apes for this research. The performance of their system was compared to other search engines based on analysis of precision and recall as well as a user trial. Although it was noted that the comparison may be unfair due to differences in the indexing methods used, they conclude that their

[2] The Dublin Core Metadata Initiative, `http://dublincore.org/`

application mostly outperforms other search engines, based on the precision and recall of image search results.

Khan et al. developed an ontology-based model for automatic generation of metadata for audio and to aid in the retrieval of audio information [6, 7]. The traditional keyword-based technique of information retrieval is described, where the documents retrieved are ones where some keywords provided by the user are present. They point out that there are limitations to this technique as it does not take into account semantic information that may be present in the document, i.e., the document could be precisely what the user is looking for without actually containing any of the search words provided by that user. In order to demonstrate how their technique performed in comparison to keyword-based techniques, Khan et al., tested their ontology-based model against the vector space model which is the most widely used model for keyword-based search techniques. Analysing precision, recall and F score, which is an overall combination of precision and recall, they concluded that overall their technique outperforms that of keyword-based search.

Davies and Weeks introduce QuizRDF as an information-seeking system for the world wide web, that browses RDF annotations of websites in addition to using traditional keyword queries [8]. It is described as a tool that when provided with an appropriate ontology can arrange information into the predefined classes of the ontology, which allows for the exploitation of interrelationships between selected pieces of information. It is argued that putting information into a meaningful context in this way aids users to efficiently manage and use information. Users of QuizRDF can browse the ontology from an "interesting" node which is defined by the standard keyword search query they provided for the search. It is argued that combining this browsing ability with standard keyword search more fully supports a users information-seeking task.

2.1 Discussion

The limitations to traditional information retrieval as described by Khan et al., can be applied to the retrieval of image media. When images are retrieved based on matching search keywords and keyword tags, images that are semantically related to the query, but fail to be associated with the appropriate tag, will not be retrieved. This challenge is amplified by the subjectivity of image tagging. Even if a searcher has a particular image in mind it is highly possible they will fail to provide an appropriate search term to match a tag associated with that image. This is especially troublesome in the case of poorly tagged images.

Using ontologies we bridge this gap between contributor and searcher, by providing relevant and semantically similar recommendations for a user to redirect their search. These query recommendations also address the problems described by Baeza-Yates et al. Users of stock photo sites are not likely to require the most popular results related to their query. Advertisers, for example, are likely to want to use images that are different to that of their opponents. With this in mind the queries recommended are suitable for inspiring the searcher to redirect

their search in a more appropriate direction. One they may not have thought of without the aid of the recommendations.

Since the focus of this research is on improving interactions with stock photo libraries, it is important to note that users should not need to know about ontologies or the way search works. To this end we avoid changing the interactions largely as occurred in the approach adopted by Hyvönen et al. By using a support tool to generate recommendations a user maintains their familiar search interactions, while gaining the benefit of the recommendations, without the need to learn a new tool. The recommended queries are provided in a similar fashion to those of QuizRDF. The first node is the original search term provided by the user and forms the root of a browsable tree of selectable terms.

While the results of evaluation performed by Schreiber et al., prove ontologies to be of benefit to both search and annotation it is of great importance to this research to focus evaluation on the user experience. Rather than analysing precision and recall of different search techniques, we analyse how ontology-based query recommendations effect the users interactions and their ability to successfully retrieve satisfactory results.

3 Implementation

The following subsections outline the domain specific ontologies that were required for this research and the development of our keyword generation support tool.

3.1 Ontology Development

We used ontologies to represent three domains for image search: Locations, Subject, and Theme. These were chosen on the basis that in general photographs will have a location associated with it, have a subject in the photograph (e.g., an animal, person or thing: animals were represented for this project) and will often have some theme attached such as emotion or behaviour. Combined, they comprise the "imageSearchOntology" used in the keyword generation system and involve over one thousand instances and over two thousand relationships.

It is common for users to search for photos that have a certain theme. We represent themes as having the concepts emotion and behaviour (as shown in Figure 1). The basis for the relationships and individuals involved with the emotion concept is Robert Plutchik's wheel of emotions [9]. This consists of eight basic emotions and eight advanced emotions, which are each composed of two of the basic ones. This relationship is represented in the ontology by "isCombinationOf" and "contributesTo" properties. For example, "Joy" is a basic emotion that contributes to "Optimism" and "Love". Alternatively we can say "Optimism" is an advanced emotion that is a combination of "Joy" and "Anticipation". Plutchik also observes that emotions can be the trigger of behaviour. This is represented in the ontology by "mayResultIn" and "mayBeConsequenceOf"

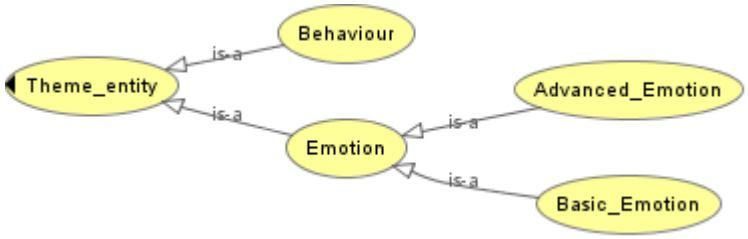

Fig. 1. The Theme Ontology

properties. For example, the emotion "Fear" may result in the action/behaviour "Jump". Symmetrically, "Jump" may be a consequence of "Fear".

The locations ontology comprises concepts including "World", "Continent" and "Continent Region". These concepts have properties such as "subRegion" and its inverse which allow us to describe for example, a continent as being a subRegion of the world. The subject ontology is focused on the animal domain. It describes the different species of animals, e.g., canine and feline and the different types of animal that belong to said species.

3.2 Ontology-based Keyword Generation System

The ontologies described in the last subsection are used in a keyword generation system developed by us. This is a stand-alone system which can be used for search applications. Figure 2 illustrates how this system can be used within a search application. The system comprises an ontology database, which holds the ontology information, and a Java application that takes in a term and generates additional information related to the term.

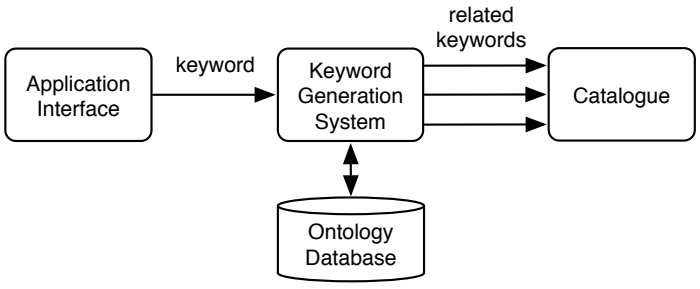

Fig. 2. System Overview

On receipt of a term from the user the system queries the database to see if that term is present in the ontology. If the term is not present there is no work to be done and the system responds with the original search term in order to allow the calling application to continue its work. The situation where the term is an instance or a class in the ontology are treated differently and are described in the following subsections. All information retrieved is stored as nodes in a tree model that may be displayed by the calling application. In the case where there are no similar instances or the term is a class, the only child of the root node is the original term provided by the user application.

Term as an Instance When the system successfully identifies the term provided as an instance in one of the available ontologies, it proceeds to generate new terms. Starting with the first child of the root and walking the ontology tree using pre-order traversal the system recursively checks for the properties available for the instance at each node. In order to assure that only relevant terms are retrieved, only specific properties are allowed to be invoked in this case. These include "subRegion", which will specialise an instance in the locations ontology, and all the properties included in the emotions ontology as they expand on an instance without becoming irrelevant. The relevant property objects are invoked to retrieve the instances that hold a relationship with the current instance. After each property invocation a list of terms is returned. A child node is added to the current node with a relevant label (such as "has subregions:" when invoking the SubRegion object). The list of children retrieved is then added as children to this "label" node and moving on to the next node in the model, the process continues recursively.

Should an instance not have any properties the system retrieves all its siblings and adds them as children to the label "may be of interest:" which is added to the root node. A sibling instance is one which belongs to the same class in the ontology. Although they are related to the original term by type they may or may not be of relevance to the user. At the end of this process the tree model contains all relevant, and specialised terms that can then be used by the user application (such as the ones shown in Figure 3).

Term as a Class When a term provided by the user is found to be a class in the ontology we query the database to retrieve instances of that class (if they exist). An example of this would be if the term provided was "dog". This is the name of a class in the subject ontology that has instances including "Sheepdog", "Greyhound", "Great Dane", which are added to the tree model as child nodes to the original term. The system then checks if there are any child classes to the original class retrieved. For example, if the original class found is "animal" its child classes "canine", "feline", and so on, will be retrieved. The previous two steps are performed recursively until all instances of all relevant classes are retrieved and added to the tree model. When all nodes have been processed the tree model has all the additional information to be returned to the calling application.

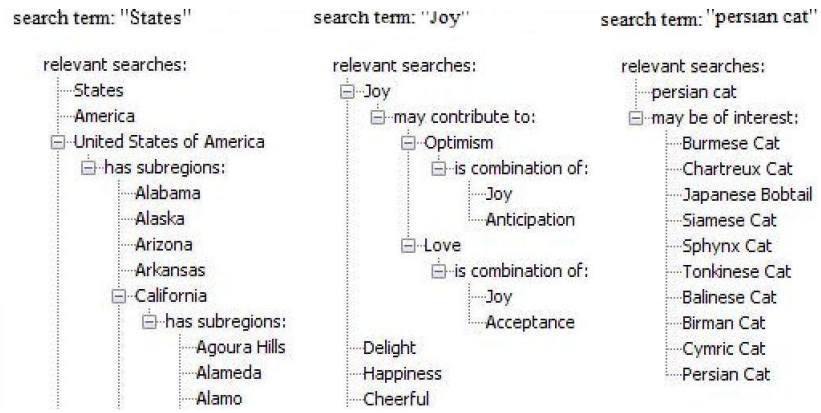

Fig. 3. Screenshots of tree models generated from terms provided by a user of the search application

Special Cases It is possible that a term provided will match to more than one instance in the ontology. For example the term "Dublin" will map to instance "Dublin" which is a region in Leinster and "Dublin" which is a region in California. In the case of such ambiguity, all possible matches are provided to allow the user to make the appropriate selection.

4 Evaluation

In order to evaluate the impact of the ontology-based keyword generation tool as a support to existing techniques two search applications were developed. The interfaces to the applications are identical at start up. The ontology-search application has an additional panel for the browsable search terms, which is only made visible when the information is available. Both search applications used Flickr to search with the keywords provided by a user. The evaluation methodology used is described and the results are discussed in the rest of this section.

4.1 Evaluation Methodology

Our evaluation had eight participants in total (all Computer Science undergraduate students). Five of the participants reported themselves as experienced image searchers, one said they were average, and the remaining two noted that they were inexperienced in searching for images. None of the participants had any experience with ontologies. All participants were surveyed at various stages of the experiment in order to allow them to describe what they liked/disliked about the application in use.

Each user was given a eight tasks to perform. The first four tasks asked the user to search for specific images. The second four tasks asked the user to find

images that meet a specification (e.g., find an image that the user thinks portrays a positive emotion). Each user performed two of each of type of task using ontology search and two using standard search and no user performed the same task on both systems (in order to avoid learning bias in their searching process). By examining how users completed these tasks we gained an understanding of the user's experience with each of the systems. Users were timed for each task and the number of times they redefine their search query was recorded. This information as well as information provided by the user about their experience allow us to draw conclusions on the effectiveness of ontology-search when compared to standard-search.

4.2 Evaluation Results

Using both search types, users found the first four tasks much more difficult than the final four. These tasks involved the user looking at a picture and trying to figure out what search terms they should use in order to find it. The final four tasks involved searching based on the descriptions discussed earlier in this section. The amount of time a user spent on a single task varied greatly between the first four tasks and the final four tasks. Based on comments provided by the users this was due to the first four tasks requiring very specific search queries in order to be found. The final four tasks were more ambiguous and allowed them to rely on their own description of what they were looking for rather than what the contributor of the image tagged it as.

Users spent a lot less time on three out of the first four tasks when using the ontology-search application (as illustrated in the leftmost chart in Figure 4. The right-most chart in Figure 4 illustrates that users were more successful completing the first four tasks with ontology search than standard search (all users successfully completed tasks 5-8 with both types of search). User comments suggest that this was due to the suggestions provided by the ontology. One user commented that ontology search provided "options that you wouldn't think of". Another user stated that the ontologies "help to filter potentially a lot of images which saves time". These comments are supported by the middle chart in Figure 4, which shows the average number of query refinements made in each task for both systems. Recall that a query refinement includes changing the term(s) provided in the text area of the interface as well as selecting a term from the additional ones provided in the ontology panel. In three of the first four tasks the user needed to refine their search less often using the ontology-search application. This combination of results as well as generally supportive user comments allow us to conclude that the additional terms provided by the ontologies aided the users in choosing an appropriate term to find the image they were searching for.

When faced with the more ambiguous final four tasks the results show that there is less difference in the number of query refinements and length of time spent on each task. On average users spent slightly more time and refined their search query more often with the ontology-search application. According to the user surveys this was due to the user being inspired to redirect their search to

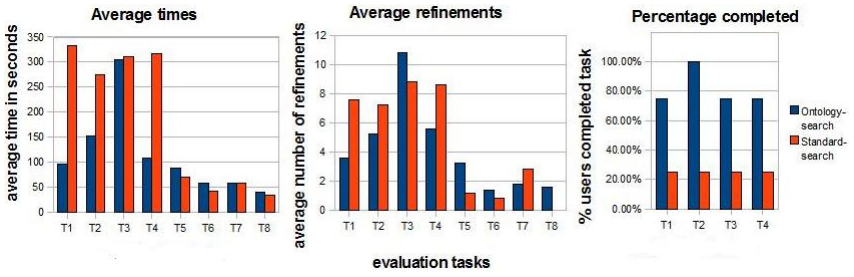

Fig. 4. Bar charts showing the average time taken to complete tasks, the average amount of refinement needed, and the percentage of users who completed each of the first four tasks.

a more appropriate term provided by the ontology. Users remarked that the ontologies provoked them to redefine their queries to terms they hadn't previously thought of. The more experienced searchers refined their query less often than others. Users were more satisfied with their end result when using the ontology-search application. While there is no great quantitative difference between the two in the case of these more general tasks there is support for our opinion that using ontologies in this way aided our searchers in some qualitative way. While there was an increase in the number of refinements made using ontology-search, we argue that this was of benefit to the user as they were more satisfied with the end result of their search.

None of the users found the ontologies difficult to use although one did note that they did not understand how to use the information provided by the ontologies until the end of the first task. While most of the users thought there was no difference in the ease of use between the two systems, all users preferred the ontology-search application over standard-search. The reasons given for this preference were due to the additional search terms provided by the ontologies. When commenting on the information provided by the ontologies users were satisfied that the terms were relevant and useful to each task they performed.

5 Conclusions

The aim of this research was to develop a support tool that will improve the interactions of users with stock photo sites. An ontology-based keyword generation tool was developed for this purpose, which uses domain specific ontologies in order to generate search term recommendations.

Search applications using Flickr were developed to simulate the interactions with stock photo sites. These were used to evaluate the keyword generation system. Evaluation demonstrated that the ontology system benefits searchers of photos. Users participating in the trial were able to perform more complex searches (i.e., the first four search tasks) using the ontology-search application,

which they could not successfully complete as often using the standard search. The evaluation results of this work as well as those of the related research discussed in Section 2, indicate that an ontology-based keyword generation system can improve interactions with standard and image search engines. This work allowed for improvements while minimising the changes to how users interact with a search interface. Domain dependant ontologies have proved an effective source for generating additional keywords that are both accurate and relevant to a particular search keyword. While the evaluation performed in this research focused on a small sample of users, related research suggests that further evaluation would likely support this conclusion.

There are possible extensions to this work that could further improve interactions with stock photo sites and image search engines in general. Allowing a user to add their search term to the ontology should it not already be present is one example. There have been a number of techniques used with an aim to improving image search, for example, ontologies, pattern recognition in images and analysis of previous searches. Although there are papers documenting the comparison between each of these techniques and standard search techniques, over the course of this research one could not be found that compared these newer techniques to each other. It would be of great benefit to the field for such a study to be undertaken and the comparison made between the effectiveness of these techniques.

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