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CASIS: A System for Concept-Aware Social Image Search

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ABSTRACT

Tag-based social image search enables users to formulate queries using keywords. However, as queries are usually very short and users have very different interpretations of a particular tag in annotating and searching images, the returned images to a tag query usually contain a collection of images related to multiple concepts. We demonstrate CASIS, a system for concept-aware social image search. CASIS detects tag concepts based on the collective knowledge embedded in social tagging from the initial results to a query. A tag concept is a set of tags highly associated with each other and collectively conveys a semantic meaning. Images to a query are then organized by tag concepts. CASIS offers superior social image search experiences by choosing the most suitable retrieval methods and concept-aware image organizations.

Categories and Subject Descriptors

H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval—Information Filtering

Keywords

Flickr, TagIR, Tag Concept, Tag Relation, Image Search

1. INTRODUCTION

The availability of social tags on various image sharing platforms (e.g., Flickr) raises the opportunity of building effective tag-based social image retrieval systems. In contrast to content-based image retrieval paradigm, which searches for visually similar images of a given query image, tag-based image retrieval (TagIR) enables users to formulate semantic queries using textual keywords through an interface similar to Web search engines. Interestingly, similar to general Web search queries, the queries for tag-based image search are usually very short, consisting of 2.2 tags on average for each search [10].

A short query, particularly a single-tag query, usually leads to a large number of potentially relevant images. More importantly, these images often represent multiple concepts because: (i) a single-tag has limited expressiveness in precisely defining the information need, and (ii) social tags are noisy in nature as different users might have very different understandings of a particular tag in annotating and searching images. Figures 1(a) and 1(b) depict the search results of two sample single-tag queries, $Q_s$ (rock) and $Q_s$ (sea), respectively. Observe that the results of $Q_s$ capture two different concepts. Specifically, the highlighted images (in green border) are about rock music while the other images are related to stone or mountain. Similar phenomenon is observed for $Q_r$. Although most images returned for $Q_r$ are good matches to the query, the highlighted ones are mainly related to ship and the remaining ones deal with seascape (beaches, sky, clouds, etc.). This multiple concepts phenomenon might be attributed to the ambiguity of the query itself (e.g., rock) or the different aspects of the query (e.g., sea), among other reasons. Importantly, a user is usually interested in only one of the concepts and not all of them. Consequently, displaying images representing multiple concepts in a single ranked list may adversely affect image search experiences.

In this demonstration, we present a social image search system called Cassis (concept-aware social image search), which exploits the notion of tag concept (or simply concept) to address the aforementioned problem. The intuition is that a specific meaning or aspect of a short (particularly single-tag) query can be well described by a group of highly related tags. Each such group of tags is referred to as a tag concept. Accordingly, images matching the query can be organized into groups, each of which matches one tag concept. For instance, Figure 2 depicts the reorganization of the search results of $Q_r$ (rock) and $Q_r$ (sea) in Cassis according to their corresponding tag concepts. Note that, Cassis supports queries consisting...
of single or multiple tags. In this paper, we mainly use single-tag queries for illustration purpose.

Intuitively, for a given query, Casis retrieves a set of images best matching the query mainly based on the relevance scores between the query tag(s) and the images. This list of images serves as the initial search results to be presented to the user. From the initial results, the co-occurring relationships among the frequent tags are identified to form a Tag Relation Graph (TRG). A node in a TRG is a tag and the weight of an edge between two tags represents the strength of the co-occurrence of the two tags. Figure 5(a) gives an example TRG for $Q(\text{sea})$. A graph-cut algorithm is then applied to (softly) cut the TRG to form a Tag Concept Graph (TCG). A TCG is a graph with meta-nodes, each representing a group of tags. Tags in each group, linked by co-occurrence relationships, jointly represent a tag concept. The links across meta-nodes indicate the relationships between tag concepts. Note that two tag concepts associated with a query may be unrelated (e.g., rock music and rock stone) or related (e.g., ship and seascape) to each other. The concepts may also overlap if they share some identical tags. A tag concept may even subsume another by containing all the latter’s tags as semantically concepts can be defined at different levels of abstraction. For visualization, TRG and TCG are superimposed to illustrate the relationships between tags and tag concepts (See Figure 5).

The benefit of Casis is two-fold. First, the search results in Casis are better organized into groups where each group of images is relevant to a more cohesive tag concept. Note that an end user may not always be aware of the existence of such concepts due to the collaborative nature of social tagging. Different users may use the same tag for different purposes and in very different manners. Hence, the tag concepts provide a superior mechanism to browse the search results. Second, by automatically identifying the tag concepts, the original tag query can be enriched by adding the concept-specific tags. As the information need is now much more clearly defined, accurate image search results are expected for different clustering techniques. These two key differences pose new challenges toward realizing concept-aware social image search. Particularly, it is important for Casis to provide an intuitive user interface to facilitate quick judgment of relevance as well as the flexibility in browsing multiple tag concepts.

2. RELATED WORK

Image Search Results Clustering. Most approaches for clustering image search results exploit low-level visual features [3]. However, these approaches suffer from two problems: (a) semantic gap between the low-level features and high-level semantics and (b) low efficiency due to curse of dimensionality. IGroup [12] took a step towards addressing these limitations by exploiting textual features such as image captions, snippets, surrounding texts. The clustering is then accomplished by combining both visual features and textual features. In the context of social tagged images, shared nearest neighbors algorithm (snn) was applied to cluster images in a collection using both tag features and visual features [5]. In Casis, we aim to detect the concepts associated with a tag query and group the images according to the detected concepts. To be detailed in the next section, Casis is flexible enough to easily accommodate different clustering algorithms (snn could be one of them).

Tag-based Image Browsing. Using tags in searching and browsing social images has been explored from multiple dimensions. The systems presented in [4] and [1] explore temporal and spatial dimensions, respectively. Other systems utilize multi-faceted browsing to produce coherent image groups. The facets can be manually specified [11] or automatically detected using WordNet [7] or Wikipedia [6]. MediaFaces [11] extracts location, celebrity, movie entities from pre-determined sources such as Yahoo!Travel, GeoPlanet, Wikipedia, etc. A query is then mapped to a stored entity whose related facets are then used to produce groups of semantically related images. Olive [7] extracts concepts from WordNet nouns for faceted browsing. WordNet, however offers relatively low coverage for the fast-changing keywords such Flickr tags. To address this problem, Wikipedia is considered in [6] for improving the coverage which is then used in TagExplorer [8], a faceted browsing system for Flickr photos. Different from faceted browsing where the facets are often pre-determined, Casis detects tag concepts automatically in real-time from the tagged images.

Tag-based Image Searching. Concept-aware social image search relies on an effective TqIR ranking method to retrieve the images that best match the query before these images can be grouped into different concepts. In Casis we adopt the TqIR framework consisting of five orthogonal dimensions for flexibly defining a specific TqIR ranking method [10]. The five dimensions include tag relatedness, tag discrimination for measuring the degree of effectiveness of a tag describing the tagged image, tag discrimination for quantifying the degree of discrimination of a tag with respect to the image collection, tag length normalization analogous to document length normalization in Web search, query matching model for computing matching score between an image tag and a query tag, and query model for retrieving tag queries. A systematic evaluation of hundreds of TqIR methods is reported in [10]. In [9], we show that tag concepts can be used to improve image tag recommendation.

3. SYSTEM OVERVIEW

In this section, we give an overview of the Casis system. Figure 3 depicts the system architecture. The tagged image retriever...
module retrieves a relatively large number of images for further processing by the initial results processor. The latter delivers the final results to the user through the user interface. We elaborate on various modules and components in turn.

### 3.1 User Interface

Recall that the user interface design is crucial in addressing the challenges in concept-aware TaxIR. Figure 4 depicts the main GUI of Casis using the query \( Q_{\text{sea}} \). It consists of three panels. User issues a tag query by keying keyword(s) and the desired number of \( h \) image hits in the search panel (Panel 1). Clicking on the Casis label (purple color) will invoke the configuration dialog box to set various parameters. Once the query is processed, the top- \( h \) image hits are displayed in the first tab (labeled “All”) in result panel (Panel 2). When we mouse over each image, its associated tags are displayed sorted by descending order of tag relatedness. Clicking on tab \( id \) on the top-left corner of the result panel displays the top- \( h \) image hits for the concept \( id \). For example, in Figure 4, the image hits for the tag concept ship, boat are displayed in Panel 2. The corresponding tag concept \( id \) is highlighted in the tag concept graph visualized in Panel 3, showing the relationship between tags within and across the concepts. Mouse hovering on the other parts of the \( \text{tgg} \) brings up other concept \( ids \). Double-clicking a tag in the graph refines the query by adding the tag into the query box in Panel 1. The \( \text{tgg} \) visualization is implemented using Prefuse package\(^2\) allowing color-coded tag concepts with overlapping and containment relationships. Mouse hovering a large concept may reveal sub-concepts contained in it. Tag concepts are visualized using different background colors.

### 3.2 Tagged Image Retriever Module

Given a query \( Q \) containing one or more query keywords, this module retrieves top- \( N \) images that best match \( Q \) where \( N \) is the predefined size\(^1\) of initial search results (default setting \( N=5000 \)). Most TaxIR algorithms can be adopted by this module, and in our implementation, we adopt the framework in [10] for supporting various settings in TaxIR (see Section 2). This module relies on two databases, the tagged images and the tag index where the tag features are extracted by Global Tag Feature Extractor. The indexes are implemented using MySQL and Lucene, respectively. The images in the initial search results are then indexed in an in-memory Lucene index for further processing. This in-memory index will be used to search for concept-specific images.

**Global Tag Feature Extractor.** This component extracts query-independent tag features (e.g., tag frequency, tag relatedness, tag associations, etc.) from the collection of social images. We briefly discuss a subset of features used in Casis. Tag frequency of a tag \( t \) is the number of images annotated with \( t \). Tag co-frequency between two tags \( t_1 \) and \( t_2 \) is the number of images annotated by both \( t_1 \) and \( t_2 \). These two features are used to compute tag associations (or co-occurrences) using different measures (e.g., Jaccard coefficient, Pointwise Mutual Information, Pointwise KL divergence). To support the framework in [10], the tag relatedness between an image and any of its annotated tags is computed and stored. The default tag relatedness is by neighbor voting. A tag \( t \) receives a high relatedness score towards image \( d \) if many of the nearest neighbors of \( d \) by visual similarity are also annotated by \( t \).

### 3.3 Initial Results Processor Module

This module is responsible for constructing query-dependent tag relation graph and tag concept graph. We detail the three major components in this module.

**Local Tag Feature Extractor.** This component first extracts the tags that are most related to the query tags from the initial results. Hence the tags and their features extracted are query-dependent. The features for the tags include tag frequency and tag co-frequency for constructing tag relation graph. Given that there can potentially be a large number of distinct tags associated with all the images in the initial results, the key issue here is to determine which tags to consider for subsequent processing.

Let \( T_q \) be the set of tags associated with an image \( d \). For each image, we extract its top- \( r \) related tags ordered by tag relatedness, where \( r = \max(\tau, \lceil \rho * |T_q| \rceil) \). Both \( \tau \) and \( \rho \) are configurable in Casis (\( \rho = 0.1 \) and \( \tau = 4 \) by default). In other words, for each image, we want to consider a reasonably small set of tags that best visually describe the image. The main reason is that tags are noisy in nature and as a result many of them do not effectively describe the images. On the other hand, some images may not be well tagged and \( |T_q| \) can be very small; \( \tau \) is introduced to avoid a very small \( r \). The extracted tags are then considered as candidate tags for constructing the tag relation graph, and subsequently tag concept extraction.

**Tag Relation Graph Constructor.** This component constructs the tag relation graph (\( \text{tgg} \)) from the initial results. The nodes in a \( \text{tgg} \) are the most frequent tags among the candidate tags identified by the local tag feature extractor with respect to the tag frequency in the entire dataset. Let \( D_Q \) be the initial results for query \( Q \), and \( D \) be the entire dataset. The normalized relative frequency of a tag \( t \)

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\(^1\)http://prefuse.org/

\(^2\)If a query has fewer than \( N \) matching images, then all matching images are retrieved.
For each detected concept, its tags are used to refine the query with diﬀerent possible concepts. Casis supports soft-clustering enabling overlapping and subsumed tag co-occurrence. Specifically, for each tag in the tag concepts from the Tag Concept Graph Constructor. 

With second-order co-occurrence, edge weights between any pair of nodes in a TRG are likely to be non-zero, making the TRG almost a complete graph. Thus, the edges are further ﬁltered using k-nearest neighbor and ε-neighborhood models. The k-nearest neighbor model keeps top-k highest weight edges for each node. The ε-neighborhood model prunes all edges whose weights are below a threshold ε. In Casis, we set k = 5 and ε equals to the median of all edge weights.

**Tag Concept Graph Constructor.** Finally, this component detects tag concepts from the TRG using an existing graph-cut or clustering algorithm. Notably, this component is designed to seamlessly incorporate diﬀerent clustering algorithms (both hard and soft clustering) with diﬀerent conﬁgurations, allowing users to explore diﬀerent possible concepts. Casis currently supports ﬁve clustering algorithms, namely, Border Flow (bf), Chinese Whisper (cw), K-Nearest Neighbor (knn), Affinity Propagation (ap), and Markov Clustering (mcl) (mainly based on the Cluster Visualization Kit1). As it is unrealistic to predict the number of concepts in a search, we choose those clustering algorithms which do not require the number of pre-deﬁned clusters. Among them, bf, cw, and mcl support soft-clustering enabling overlapping and subsumed tag concepts. Figures 5(b), 5(c), and 5(d), show the concepts detected for Q(sea), knn, mcl, and ap, respectively. The concepts detected by bf are shown in Figure 4. Note that, the query tag (i.e., sea) is not shown in TRG or QG as it is related to all tags and all concepts.

For each detected concept, its tags are used to reﬁne the query to get the concept-speciﬁc results from the initial results, and then display them under a numbered tag (id) in the result panel. That is, Casis presents both the tags (and their relationships) deﬁning each concept and the corresponding image results for the concept.

**4. DEMONSTRATION OVERVIEW**

Our demonstration will be loaded with nus-wide dataset. The original tags (without cleaning) of images are used in this demonstration. All global features (e.g., tag frequency, tag association, tag relatedness) are pre-computed by Global Tag Feature Extractor.

Using this dataset, we aim to showcase the functionality and eﬃciency of Casis in identifying multiple tag concepts and presenting concept-aware TaoIR results. Speciﬁcally, we shall showcase the followings.

**Tag Relation Graph and Concept Graph.** Through our gui, we shall demonstrate how Casis identiﬁes closely related tags as concepts from the initial query results, and visualizes tag relationships within and across tag concepts. We shall also showcase the eﬀect of various tag association measures and clustering algorithms for concept detection problem.

**Concept-Aware Image Search and Results Browsing.** Using Casis, we shall demonstrate concept-aware image search in action and real-time visualization of results categorized by concepts. Recall that tags in concepts are also good candidate tags for query reﬁnement. Hence, end users will also be able to interactively experience superior topic-speciﬁc social image search when they select some of the tags (by clicking nodes in TRG) to reﬁne their queries.

5. REFERENCES


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