Searching the Web for Peculiar Images based on Hand-made Concept Hierarchies

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***Abstract*—Most researches on Image Retrieval (IR) have aimed at clearing away noisy images and allowing users to search only acceptable images for a target object specified by its object-name. We have become able to get enough acceptable images of a target object just by submitting its object-name to a conventional keyword-based Web image search engine. However, because the search results rarely include its uncommon images, we can often get only its common images and cannot easily get exhaustive knowledge about its appearance (look and feel). As next steps of IR, it is very important to discriminate between "Typical Images" and "Peculiar Images" in the acceptable images, and moreover, to collect many different kinds of peculiar images exhaustively. This paper proposes a method to search the Web for peculiar images by expanding or modifying a target object-name (as an original query) with its hyponyms based on hand-made concept hierarchies such as WordNet and Wikipedia.**

***Keywords*-image retrieval; query expansion; peculiar images; Web search; concept hierarchy; semantics; thesaurus;**

I. Introduction

In recent years, various demands have arisen in searching the Web for images as well as documents (text) to utilize them more effectively. When a name of a target object is given by a user, the main goal of conventional keyword-based Web image search engines such as Google Image Search [1] and most researches on Image Retrieval (IR) is to allow the user to clear away noisy images and search only the acceptable images for the target object-name, which just include the target object in their content, as precisely as possible. However, the acceptable images for the quite same object-name are of great variety. For instance, in different shooting environments such as angle, distance, or date, in different appearance varying among individuals of the same species such as color, shape, or size, with different background or surrounding objects. Therefore, we sometimes want to search not only vague acceptable images of a target object but also its niche images, which meet some kind of additional requirements.

One example of more niche demands, when only a name of a target object is given, is to search the Web for its "Typical Images" [2] which allow us to adequately figure out its typical appearance features and easily associate themselves with the correct object-name, and its "Peculiar Images" [3–5] which include the target object with not common (or typical) but eccentric (or surprising) appearance features. For instance, most of us would uppermost associate "sunflower" with "yellow one", "cauliflower" with "white one", and "sapphire" with "blue one", while there also exists "red sunflower" or "black one" etc., "purple cauliflower" or "orange one" etc., and "yellow sapphire" or "pink one" etc. When we exhaustively want to know all the appearances of a target object, information about its peculiar appearance features is very important as well as its common ones.

Conventional Web image search engines are mostly Text-Based Image Retrievals by using the filename, alternative text, and surrounding text of each Web image. When such a text-based condition as a name of a target object is given by a user, they give the user the searched images which meet the text-based condition. It has become not difficult for us to get typical images as well as acceptable images of a target object just by submitting its object-name to a conventional keyword-based Web image search engine and browsing the top tens of the search results, while peculiar images rarely appear in the top tens of the search results. As next steps of IR in the Web, it is very important to discriminate between "Typical Images" and "Peculiar Images" in the acceptable images, and moreover, to collect many different kinds of peculiar images as exhaustively as possible.

My previous works [3], [4] have proposed a method to search the Web for peculiar images of a target object whose name is given as a user's original query, by expanding the original query with its peculiar appearance descriptions (e.g., color-names) extracted from the Web by text mining techniques [6], [7] and/or its peculiar image features (e.g., color-features) converted from the Web-extracted peculiar color-names. And to make the basic method more robust, my previous work [5] has proposed a refined method equipped with cross-language (translation between Japanese and English) functions like [8], [9]. As another solution, this paper proposes a method to search the Web for peculiar images by expanding or modifying a target object-name (as an original query) with its hyponyms based on hand-made concept hierarchies such as WordNet [10] and Wikipedia [11].

II. Method

This section explains a method to precisely search the Web for “Peculiar images” of a target object whose name is given as a user’s original query, by expanding the original query with its hyponyms based on hand-made concept hierarchies such as WordNet and Wikipedia.

Figure 1 gives an overview of my Peculiar Image Search based on hand-made hyponym relations, while Figure 2 gives an overview of my previous Peculiar Image Search based on Web-extracted color-names.

Step 1. Hyponym Extraction

When a name of a target object as an original query is given by a user, its hyponyms are extracted from hand-made concept hierarchies such as WordNet and Wikipedia. Of course, they could be automatically extracted from exploding Web documents about the target object by text mining techniques [12–14]. The former is precision-oriented, while the latter is rather recall-oriented. Therefore, this paper adopts the former as a solution of the 1st next step of IR to precisely discriminate between “Typical Images” and “Peculiar Images” in the acceptable images.

Step 2. Query Expansion by Hyponyms

Here, we have two kinds of clues to search the Web for peculiar images: not only a target object-name o (text-based condition) as an original query given by a user, but also its hyponyms h (text-based condition) extracted from WordNet and/or Wikipedia in the Step 1.

The original query (q0 = text: `["o"]` & content: null) can be modified or expanded by its hyponym h as follows:

q1 = text: `["h"]` & content: null,
q2 = text: `["o" AND "h"]` & content: null.

This paper adopts more conditioned latter to precisely search the Web for its acceptable images and “Peculiar Images”.

Step 3. Image Ranking by Expanded Queries

This paper defines two kinds of weights $\text{pis}_{1/2}(i, o)$ of Peculiar Image Search based on the expanded query (q2 = text: `["o" AND "h"]` & content: null) in the Step 2.

The first (simpler) weight $\text{pis}_1(i, o)$ is assigned to a Web image i for a target object-name o and is defined as

$$\text{pis}_1(i, o) := \max_{\forall h \in H(o)} \left\{ \frac{\text{hyponym}(h, o)}{\text{rank}(i, o, h)^2} \right\},$$

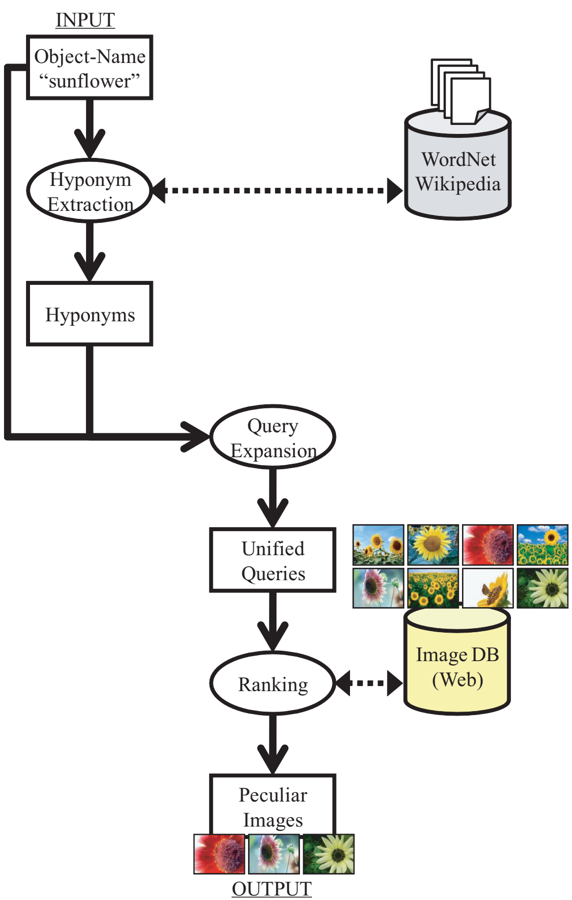


Figure 1. Peculiar Image Search based on Hand-made Hyponyms.

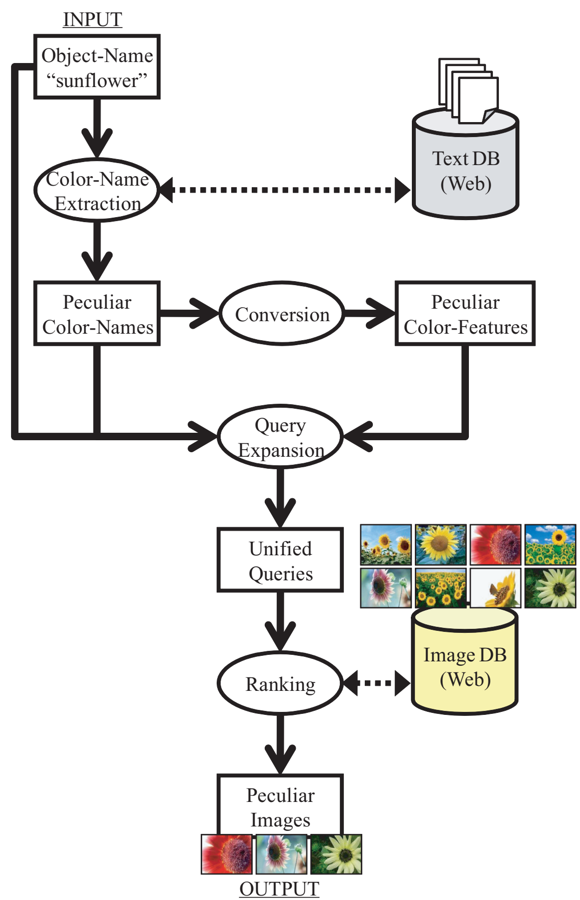


Figure 2. Peculiar Image Search based on Web-extracted Color-Names.

where $H(o)$ stands for a set of hyponyms of a target object-name o from the WordNet and/or Wikipedia in the Step 1, a Web image i is searched by submitting the text-based query `["o" AND "h"]` (e.g., `["sunflower" AND "evening sun"]`) to Google Image Search [1], and rank(i, o, h) stands for the rank of a Web image i in the search results. And hyponym(h, o) stands for the suitability of a candidate h for hyponyms of a target object-name o. In this paper, hyponym(h, o) is always set to 1 for any hyponym candidates h of a target object-name o because they are extracted from hand-made (so certainly precise) concept hierarchies such as WordNet and Wikipedia. So, the first weight can be re-defined as

$$\text{pis}_1(i, o) := \max_{\forall h \in H(o)} \left\{ \frac{1}{\text{rank}(i, o, h)^2} \right\}.$$

The second (more sophisticated) weight $\text{pis}_2(i, o)$ using the suitability ph(h, o) is assigned to a Web image i for a target object-name o and is defined as

$$\text{pis}_2(i, o) := \max_{\forall h \in H(o)} \left\{ \frac{\text{ph}(h, o)}{\text{rank}(i, o, h)} \right\},$$

where ph(h, o) stands for the suitability of a candidate h for Peculiar(-colored) Hyponyms of a target object-name o,

$$\begin{aligned} \text{ph}(h, o) &:= \text{hyponym}(h, o) \cdot \frac{|I_k(o)| \cdot |I_k(o, h)|}{\sum_{i \in I_k(o)} \sum_{j \in I_k(o,h)} \text{sim}(i, j)} \\ &= \frac{|I_k(o)| \cdot |I_k(o, h)|}{\sum_{i \in I_k(o)} \sum_{j \in I_k(o,h)} \text{sim}(i, j)}, \end{aligned}$$

where $I_k(o)$ and $I_k(o, h)$ stand for a set of the top (at most) k Web images searched by submitting the text-based query `["o"]` (e.g., `["sunflower"]`) and `["o" AND "h"]` (e.g., `["sunflower" AND "evening sun"]`) to Google Image Search, respectively. In this paper, k is set to 100. And sim(i, j) stands for the similarity between Web images i and j in the HSV color space [15] as a cosine similarity,

$$\text{sim}(i, j) := \frac{\sum_{\forall c} \text{prop}(c, i) \cdot \text{prop}(c, j)}{\sqrt{\sum_{\forall c} \text{prop}(c, i)^2} \sqrt{\sum_{\forall c} \text{prop}(c, j)^2}},$$

where c stands for any color-feature in the HSV color space with 12 divides for Hue, 5 divides for Saturation, and 1 divide for Value (Brightness), and prop(c, i) stands for the proportion of a color-feature c in a Web image i.

III. Experiment

This section shows several experimental results for the following four kinds of target object-names to validate my proposed method to search the Web for their peculiar images more precisely than conventional keyword-based Web image search engines such as Google Image Search.

Table I
NUMBER OF HYPONYMS IN WORDNET AND/OR WIKIPEDIA.

Object-Name	WordNet	Wikipedia	both
sunflower	19	45	60
cauliflower	0	36	36
praying mantis	0	800	800
sapphire	1	15	15

Figure 3 shows the top k average precision of my proposed Peculiar Image Searches (PIS) based on hand-made concept hierarchies such as WordNet and Wikipedia, and Google Image Search. It shows that my PIS method by using the second (more sophisticated) ranking function $\text{pis}_2(i, o)$ with the suitability ph(h, o) of a candidate h extracted from (hand-made) concept hierarchies for peculiar(-colored) hyponyms of a target object-name o is superior to my PIS method by using the first (simpler) ranking function $\text{pis}_1(i, o)$ without the suitability ph(h, o) as well as Google Image Search, and that my PIS method by using Wikipedia's hyponym relations is superior to my PIS method by using WordNet's hyponym relations.

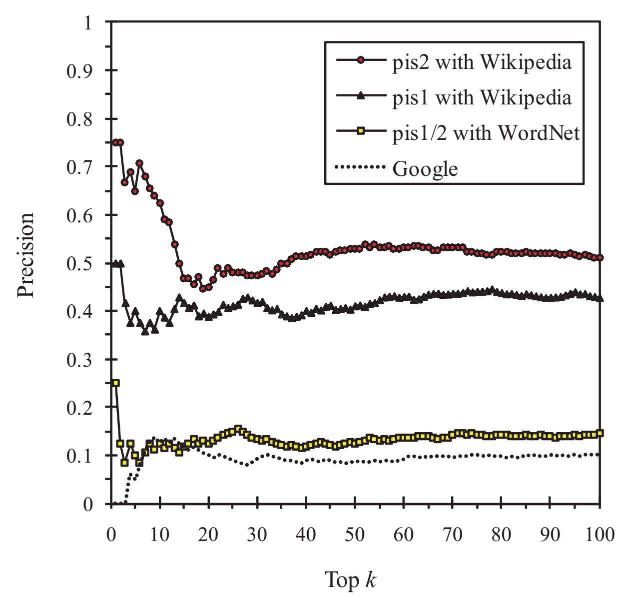
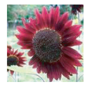
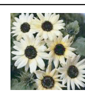
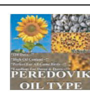
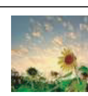


Figure 3. Top k Average Precision of Google Image Search (query: q0) vs. Peculiar Image Searches (query: q2, ranking: pis_1 or pis_2).

Table II shows the top 10 peculiar(-colored) hyponyms h of a target object-name o = "sunflower" ranked by using their suitability $\mathrm{ph}(h, o)$ for my second (more sophisticated) ranking function $\mathrm{pis}_2(i, o)$ with Wikipedia's hyponym relations. The hyponyms indicated by boldface are acceptable for its peculiar hyponyms. Several noisy hyponyms are ranked higher than the other peculiar hyponyms, e.g., "peach passion" (3.76906) ranked at 12th, "indian blanket hybrid" (3.58879) at 16th, and "evening sun" (3.43408) at 18th.

Figures 4 to 6 show the top 20 search results for a target object-name o = "sunflower" to compare between Google Image Search, and my proposed Peculiar Image Search by using the first (simpler) ranking function $\mathrm{pis}_1(i, o)$ or the second (more sophisticated) ranking function $\mathrm{pis}_2(i, o)$ based on Wikipedia's hyponym relations.

Table II
TOP 10 PECULIAR HYPONYMS OF OBJECT-NAME o = "sunflower" EXTRACTED FROM WIKIPEDIA WITH THEIR TYPICAL IMAGE.

Rank	Peculiar Hyponym h	$\mathrm{ph}(h, o)$	Typical Image
1	**velvet queen**	5.37327	
2	**italian white**	5.11842	
3	black oil	5.07947	
4	**red sun**	4.46867	
5	sunchoke	4.24779	
6	**aztec sun**	4.23808	
7	**strawberry blonde**	4.16153	
8	peredovik	3.83770	
9	**tithonia rotundifolia**	3.81871	
10	north american sunflower	3.78737	

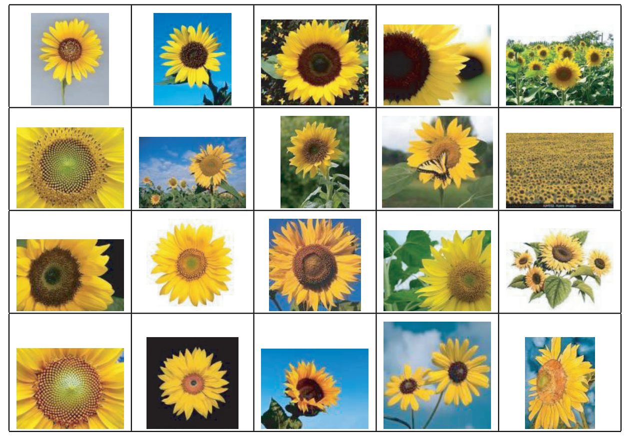


Figure 4. Top 20 results of Google Image Search (query: q0, ranking: Google, object-name: "sunflower").

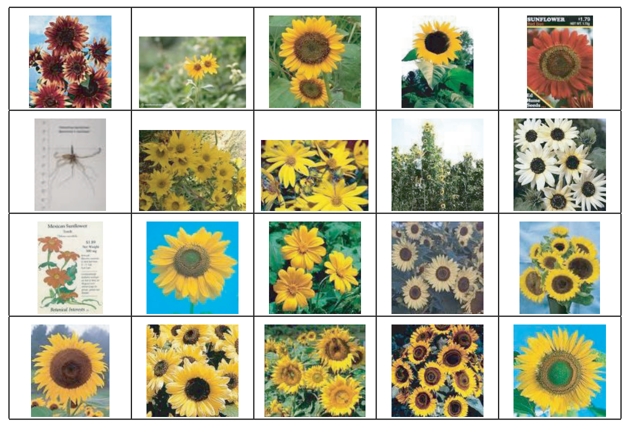


Figure 5. Top 20 results of Peculiar Image Search with Wikipedia (query: q2, ranking: $\mathrm{pis}_1(i, o)$, object-name: "sunflower").

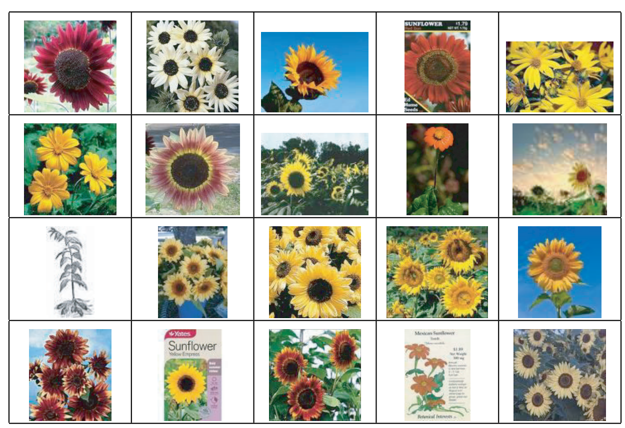


Figure 6. Top 20 results of Peculiar Image Search with Wikipedia (query: q2, ranking: $\mathrm{pis}_2(i, o)$, object-name: "sunflower").

Table III shows the top 10 peculiar(-colored) hyponyms h of a target object-name $o =$ "cauliflower" ranked by using their suitability $\mathrm{ph}(h, o)$ for my second (more sophisticated) ranking function $\mathrm{pis}_2(i, o)$ with Wikipedia. The hyponyms indicated by boldface are acceptable for its peculiar hyponyms. Several noisy hyponyms are ranked higher than the other peculiar hyponyms, e.g., "green cauliflower" (3.15210) ranked at 11th, "orange cauliflower" (3.13397) at 12th, and "romanesco broccoli" (3.03155) at 21st.

Figures 7 to 9 show the top 20 search results for a target object-name $o =$ "cauliflower" to compare between Google Image Search, and my proposed Peculiar Image Search by using the first (simpler) ranking function $\mathrm{pis}_1(i, o)$ or the second (more sophisticated) ranking function $\mathrm{pis}_2(i, o)$ based on Wikipedia's hyponym relations.

Table III
TOP 10 PECULIAR HYPONYMS OF OBJECT-NAME $o =$ "cauliflower" EXTRACTED FROM WIKIPEDIA WITH THEIR TYPICAL IMAGE.

Rank	Peculiar Hyponym h	$\mathrm{ph}(h, o)$	Typical Image
1	**purple cape**	4.64476	
2	**graffiti**	4.59797	
3	**purple cauliflower**	4.42077	
4	**violetta italia**	3.43158	
5	**minaret**	3.42849	
6	**veronica**	3.34011	
7	igloo	3.31682	
8	candid charm	3.27989	
9	mayflower	3.26645	
10	**cheddar**	3.16336	

Figure 7. Top 20 results of Google Image Search (query: q0, ranking: Google, object-name: "cauliflower").

Figure 8. Top 20 results of Peculiar Image Search with Wikipedia (query: q2, ranking: $\mathrm{pis}_1(i, o)$, object-name: "cauliflower").

Figure 9. Top 20 results of Peculiar Image Search with Wikipedia (query: q2, ranking: $\mathrm{pis}_2(i, o)$, object-name: "cauliflower").

IV. Conclusion

As next steps of Image Retrieval (IR), it is very important to discriminate between "Typical Images" [2] and "Peculiar Images" [3–5] in the acceptable images of a target object specified by its object-name, and moreover, to collect many different kinds of peculiar images exhaustively. In other words, "Exhaustiveness" is one of the most important requirements in the next IR.

As a solution, my previous works [3], [4] proposed a basic method to precisely search the Web for peculiar images of a target object by its peculiar appearance descriptions (e.g., color-names) extracted from the Web and/or its peculiar image features (e.g., color-features) converted from the Web-extracted peculiar appearance descriptions. And to make the basic method more robust, my previous work [5] proposed a refined method equipped with cross-language (translation between Japanese and English) functions.

As another solution, this paper has proposed a novel method to search the Web for peculiar images by expanding or modifying a target object-name (as a user's original query) with its hyponyms based on hand-made concept hierarchies such as WordNet and Wikipedia. And several experimental results have validated the search precision of my proposed method by comparing with such a conventional keyword-based Web image search engine as Google Image Search. They also have shown that my second (more sophisticated) image-ranking function $\mathrm{pis}_2(i, o)$ with the suitability $\mathrm{ph}(h, o)$ of a candidate h extracted from (hand-made) concept hierarchies for peculiar(-colored) hyponyms of a target object-name o is superior to my first (simpler) image-ranking function $\mathrm{pis}_1(i, o)$ without the suitability $\mathrm{ph}(h, o)$, and that the Wikipedia is superior to the WordNet as a Web source of hand-made hyponym relations for my proposed Peculiar Image Search based on (hand-made) concept hierarchies.

In the near future, as hyponyms of a target object-name, I also try to utilize Web-extracted hyponym relations [13], [14] as well as hand-made hyponym relations in the WordNet and/or Wikipedia. In addition, I try to utilize the other appearance descriptions (e.g., shape and texture) besides color-names and the other image features besides color-features in my various Peculiar Image Searches.

Acknowledgment

This work was supported in part by JSPS (Japan Society for the Promotion of Science) Grant-in-Aid for Young Scientists (B) "A research on Web Sensors to extract spatio-temporal data from the Web" (23700129, Project Leader: Shun Hattori, 2011-2012).

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