Search the Web Using GUI Screenshots

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ABSTRACT

This paper provides a sample of a LaTeX document which conforms, somewhat loosely, to the formatting guidelines for ACM SIG Proceedings. It is an *alternate* style which produces a *tighter-looking* paper and was designed in response to concerns expressed, by authors, over page-budgets. It complements the document *Author's (Alternate) Guide to Preparing ACM SIG Proceedings Using LaTeX2ε and BibTeX*. This source file has been written with the intention of being compiled under LaTeX2ε and BibTeX. The developers have tried to include every imaginable sort of "bells and whistles", such as a subtitle, footnotes on title, subtitle and authors, as well as in the text, and every optional component (e.g. Acknowledgments, Additional Authors, Appendices), not to mention examples of equations, theorems, tables and figures. To make best use of this sample document, run it through LaTeX and BibTeX, and compare this source code with the printed output produced by the dvi file. A compiled PDF version is available on the web page to help you with the 'look and feel'.

Categories and Subject Descriptors

H.4.m [**Information Systems**]: Miscellaneous; D.2 [**Software**]: Software Engineering; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*

General Terms

Image search

Keywords

Image search

1. INTRODUCTION

There are a lot of resources on the Web about software applications. Users can learn from these resources teach how to perform a wide variety of tasks such as setting up a home network, backing up files, or changing the speed of the mouse cursor. These resources are often created and made available online by software developers themselves who wish to maintain an online version of the documentation apart from the built-in one in order to keep the content always up-to-date (e.g., support.microsoft.com). These resources are also created by unofficial, third-party experts, for example, by sites offering tutorials and tips on various software applications (e.g., osxfaq.com), by general-purpose *how-to* sites (e.g., eHow.com) featuring software tutorials as one of the topics, and by computer book publishers who wish to make their books accessible online via subscription (e.g., safaribooksonline.com). Even more resources can be found in user-generated contents, for example, in blogs where bloggers share their experiences and tips using the software application, in discussion boards where people can discuss and learn from each other about software, and in QA communities such as Yahoo Answers where members can raise question and get answers back from other members.

However, for some users, searching this valuable resource effectively can be challenging. For example, suppose a user opens up the network properties dialog window and wishes to find out how to change the IP address. To use a search engine, this user may first type "change IP address" to describe the task he wishes to learn. He may soon realize it is also necessary to indicate which dialog window he wishes to perform the task with. To do so, he may enter additional search terms to describe the operating system, the title of the dialog window, and any other information needed to identify the dialog window. Not only is it **cumbersome to enter many keywords** but also these keywords are **prone to ambiguity** since it is hard distinguish the keywords describing the program from those describing the task. Moreover, as the user browses the links in the result, the user may find it **difficult to judge relevancy** based only on the summary text. The emphasis on second language education and the availability of free and powerful machine translation technology (e.g., Google Translate) have enabled many Web users to perform bilingual search in order to access more information beyond the confine of their native languages. However, technical articles are often **inaccessible by bilingual search**. For example, a Chinese-speaking person fluent in English may be able to retrieve useful articles on dogs in both languages using the English or Chinese word for *dog* as the search term. But when it comes to technical terms such as *system preferences*, the same person may be confined to only Chinese articles since it is not obvious how to translate these terms into English.

(The ranking in this example has been artificially adjusted in order to illustrate a rich variety of results.)

C: Use multi-modal search Brief system demo walk through a search scenario showoff the scale Explain how each limitation is overcome List of contributions Propose a new large-scale search system Evaluate it Road map

WWW2010, April 26-30, 2010, Raleigh, North Carolina.
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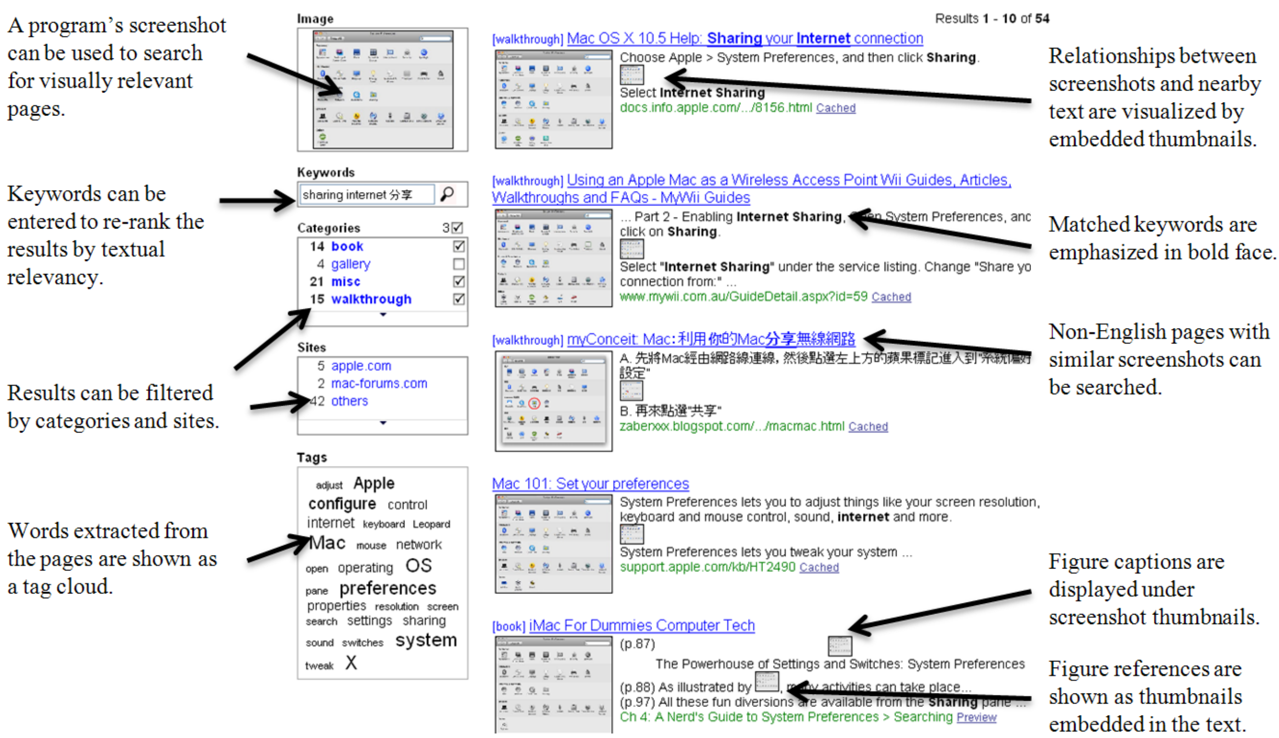

2. RELATED WORK

WWW citations about image search Vision citations

3. CHALLENGES

4. BUILDING THE DATABASE

4.1 Collecting images

We used three methods to collect screenshot images to populate our database. Currently, our prototype system contains a total of 150,000 images in its index.

First, we submitted computer-related keywords to Bing Image Search to collect screenshot images of interactive programs. To increase the likelihood of obtaining the desired images, we sampled keywords from title bars of the dialog windows of various computer programs. Some examples of these keywords are properties, preferences, option, settings, wizard, custom, installation, network, sound, keyboard ....etc. We turned on the filter feature to keep only illustration and graphics, rejecting obviously non-screenshot images such as images of faces and natural scenes. Using this method, we collected a total of 100,000 images, about 80% of them are screenshots of computer programs.

Second, we used TinEye, a reverse image search engine that can take an image as the query and return a list of URLs to nearly identical copies of the image found on the Web for copyright infringement. We manually captured screenshot images of more than 300 interactive windows of popular programs across three of the most popular OS platforms (XP, Vita, and Mac OS). These images were submitted to TinEye to obtain about 5,000 images. Since the visual similarity matching performed by TinEye is very precise, all of these images are screenshot images.

Third, we collected a library of 102 electronic books on popular software programs. We extracted all the image figures embedded in the electronic file (i.e., Pdf documents). About x% of these figures are screenshots. This method gave us about 50,000 images.

The set of images collected using each of the methods above have their own pros and cons.

Each of this method has its own pros and cons. While Bing Image Search provides the best variety of images, many of them are not visually relevant to any program at all. TinEye is able to provide visually relevant images. But these images are ranked only by visual relevancy; the page containing the highest ranked image may not necessarily contain any useful information.

Images from Bing Image Search may have the largest coverage, but they are only textually relevant to associated with the searc only by keywords and may contain many screenshots that are not visually relevant at all. TinEye are ranked purely by visual similarities; top pages may not necessarily contain any useful information. Computer books often contain the best quality text, but they cover a relatively limited scope and their contents are less up-to-date compared to the Web. By combining these three resources, we hope to create a rich repository of technical information that is both visually and textually relevant to and accessible by general computer users.

4.2 Indexing images

use hamming embedding use ransac use haedo for scalability

4.3 Extracting Text

A table summarize what features are applicable to which data type.

Give a real example of each type of text.

Title We also extract the text in the Title tag from the

HTML header. For book, the title can be too general.

Heading Some web page may contain multiple figures illustrating different parts and provide heading for each part. This heading can be more specific than the page title. However, to extracting section headings reliably is harder for books in pdf format. Some PDFs have outlines. We can extract the nearest chapter or section heading.

Alt Text ALT tag provides information redundancy in case when the image fails to be displayed or for users with visual impairment. Also, it is useful for keyword-based image search. ALT tag text can be used to determine the content of the image, allowing search to go from keyword to image. However, in our application, such text is redundant. It does not provide any additional information other than what the user already knows by reading the figure. For example, the ALT tag for the System Preferences window is System Preferences but it is already obvious by reading the title of the window.

Caption In books, figures are often clearly labeled with captions. Thus, the text in the captions are extracted. However, there's less common to add captions on web images, other than online photo albums.

Explicit reference A figure and references made to it may not be on the same page. It is necessary to search a couple pages before and after the page the figure is on. This is different from web pages. On a web page, a figure and the text about it often appears on the same page. In contrast, in a typical book page, it is not uncommon that a paragraph may refer to a figure one or two pages ahead or after the page the paragraph is on due to formatting reason. For example, a paragraph on page 100 may say *as shown in Figure 12-3* while the figure may be placed on page 101 because of formatting constraints. Also, a paragraph can make references such as *as shown in Figure 12-3.* The paragraph containing such explicit references can be useful too.

Implicit references There are also implicit references that can be mined. For example, sentences like *as shown above* or *see below* indicate that these sentences must be relevant to the figure above or below respectively. These sentences may not be immediately below or above the figure. But one thing we know is that they must be not too far from the figure. It is unlikely a paragraph may refer to a figure more than 10 pages away.

Nearby text If all above fails, we simply extract words immediately above and below the image. On web page, images and referring text tend to be on the same page. Also, relevant text tends to be very near the image added for illustration. Typically, the image is placed either above or below the text. Thus, we extract the text immediately before and after the image tag.

Figure OCR Useful text are those the user does not already know. Text that can also be found in the figure is not as useful. Thus, we apply OCR on each figure to determine what text is already embedded in each figure. While these OCR text might not be that useful to the users, since they can already read them, such text can be useful for filtering out sentences that are simply repeat of what is in the figure and thus less useful to the users.

Action phrases With interactive applications, users often care about what they can do with this interface. Because of the limit in screen real estate, it is often impossible to put in lots of text and caption to explain in details what each feature can accomplish. Such details can be found on web page. Thus, we focus on action keywords such as enable, allow, let, and extract sentences containing these action keywords near the figure.

4.4 Adding Content Type Tags

There are several distinct and useful types of resources in our application domain. We want to automatically tag them by type. In the current work, we consider four types: blog, tutorial, forum, and official documentation. We classify each page based on several simple heuristics. For blogs, we look for keywords in the URLs such as blog, wordpress ...etc. For official docs, we look for company names in the URLs such as microsoft, apple, adobe. For tutorials, we look for words such as "tutorial", "how to" ...etc and urls of well-known sites such as howto.com or answer.com. For forums, we analyze the page structure and identify features related to discussion such as threads, reply, and table formatting.

It is possible for a page to be assigned multiple tags. For example, someone can write a tutorial on his blog. Then, the page can have two tags.

4.5 Statistics

What are the websites hosting the most number of screenshots?

What are the types of websites hosting useful screenshots?

5. SEARCHING THE DATABASE

5.1 Specifying queries

There are two ways to specify image queries based on what the user is seeing.

First, we provide a Java-based cross-platform search client program. Users can download and run the program on any platform. They can select any region on the screen by stretching a rectangular box and submit the screen to the server. After receiving the response, the program will automatically load the default web browser to display the search result.

Second, users can also use our system without installing any special software. Users can use the built-in image capture utility, such as the snipping tool on Windows Vista or the Command-Shift+4 hotkey on Mac OS. After capturing a screenshot image, the user can use the submit form to send the query image to the server and see the results.

Keywords are optional in our search system. They can be specified in two ways. After capturing the image users can add a few keywords in both the client program and the online form. Alternatively, users can type keywords in the search box on the result page.

Keywords can serve two purposes. First, they can specify the content users wish to see on the returned pages. Second, they can describe the screenshot to improve the performance of visual matching. Since the screenshot matching can be done very accurately, we expect users will very quickly realize that it is not necessary to repeat the text embedded in the screenshot, since the visual search will take care of it.

5.2 Finding similar images

5.3 Ranking pages

If it's a image search application, results would be ranked purely by visual similarity. But if we do that pages without any useful text but happen to have the right image may be ranked at the top. Similarity, if it's a text search application, they would be ranked by text relevancy. But if we do that, pages with lots of useful text but with the wrong image may be mistakenly ranked at the top. Since our application is a mixed modality search application, we can not rank the results solely on either modality alone. A new ranking scheme based on a comprehensive set of features is needed. We identified N features to be important for determining the relevancy of each page for the purpose of ranking. The features can be divided into three types: visual features, text features, and site features.

5.3.1 Visual Features

Similarity If the image is not similar at all, it's unlikely the page text would contain anything useful. However, the current image matching method is very precise. We can almost assume the images returned are always correct. Images with lower scores may be cropped versions of the screenshot. But while they are relevant, they may be less useful since it is harder for users to tell instantly which parts of the interactive window this cropped screenshot is covering.

Display dimensions We consider how the image is actually displayed on the page. These are specified in the image tag the width and height fields when they are different from the actual dimension of the image file. Designers choose the ideal dimensions to display to make the images easy to see together with the text this image is meant to illustrate. If the image is too small, it may be a thumbnail for other purposes and may not be that useful. Similarly, if an image is too large, it's unlikely there's enough space left on a page to provide a lot of useful text. Or it could be the page showing the detailed view of the image. Thus, we sample a large number of screenshots and compute their average display dimensions. Then, we penalize images that are too big or too small.

Position If the image occupies the prominent position on the page, it's more likely to be something important. Image positions may not be easy to compute. Perhaps we can consider ordering. Is it the first image, or the second image?

Number of coexisting images the fewer other images a page has, the more likely the information on the page will be about the image. This count has to exclude images that are not screenshots.

5.3.2 Text Features

Amount The more text a page has, the more information users can get.

Special text Whether or not each of the N kinds of special text labels can be found on the page. Can we find a caption for this image on the page? Can we find a clear reference to this image on the page? Does this page have a title?

Search terms If the page contains more keywords relevant to those supplied by the users, the page should ranked higher. We check each location whether or not a search term can be found. The locations we consider are: title, caption, nearby text, referring sentences, same page, one page apart, two pages apart. It can be represented as a vector of integers, where each integer indicates the number of search terms found at that location. Each term is then inversely weighted by its global frequency, reducing the weight of very common words. When there's no search term given, this does not have any effect.

5.3.3 Site Features

Type Is it a blog, tutorial, or forum, or from book. It is possible the world as a whole may favor one type of resources over the other. We estimate their relative important in the following order: official doc, tutorial, blog, and forum.

Authority If an image is from Microsoft, it's more likely to contain useful information. Number of other images on the site: if a site hosts a lot of screenshot images, it's probably hosting the images for some good purposes and those images are more likely to be useful. Also, maybe some books are more trusted by users than the other books.

Quality If screenshot images hosted by a site have been consistently judged by users to be accompanied by high-quality text, it's more likely new screen images found on this site will also be accompanied by high-quality text. Initially, we do not have any of this information. We assume images on all websites have equal quality. Average ranking score of the site.

5.3.4 Learning weights

We initialize the weights based on intuition. Then we examine the results and mark those that are relevant, making adjustment to weights accordingly. At the deployment, the system can continue to improve its ranking algorithm using user feedback, in particular, click-throughs.

Offline learning. Initially, we do not have any user to train the weighting scheme. Thus, we use AMT. We randomly sample five results from the top 20 returned under the default weighting scheme. Subjects are asked to mark the most useful result and the least useful result. Each marking will give us a data point where one is better than the other. Given a set of ordering and feature vectors, we can then train the weights based on real data and find the weights that can produce a ranking that respect most number of the ordering constraints.

Online learning. Once the system is put online, it can continue to adjust the weights. Instead of using a controlled setup, we record the click-through. After accumulating enough click-throughs, we can use the ratio of numbers of click-through and number of retrieval as an estimate of the usefulness of the pages. Then, we can identify the most useful and the least useful pages in the result to obtain a ordering constraint that can be added to the training data.

5.4 Presenting the results

New presentation scheme is needed for our purpose. In text search, the keywords are highlighted, and displayed in the context of the text before and after them. In image search, only the caption, url, and dimensions are displayed. Users pay attention to images to judge visual relevancy. Also, they pay attention to the url to judge authority. In Tineye search (reverse image search), the matched images are shown as thumbnails, grouped by "exact copies", and ordered by visual similarity. The back links to the pages where matched images are found are also displayed. All these are not suitable for our purpose.

Figure shows the detail view of how a result is typically displayed. The design is very similar to how search results are typically displayed by popular commercial search engines to leverage the the familiarity users already have. It has three main fields: title, description, and source. In addition, a new field relevant to our application is the The thumbnail image next to each result.

For title, for web page results, we extract the title tag from the HTML header. Clicking on the title will bring the user to the page where the figure is located at. For book results, the title is the title of the book. Clicking on the title will bring the user to the book store where the book can be purchased. The resource type tag is displayed in front of the title.

For description, we generate a paragraph based on the set of relevant phrases extracted by the methods described in Section ??. We limit the size of the paragraph to at most 30 words and not exceeding two lines of text . The type of resource is clearly marked. The context in which the figure appears in the text is visually represented. The user can quickly read the text above or below the image. The explicitly references such as *As shown in Figure ()* is replaced by a thumbnail for quick visualization of the context. If keywords are specified, their occurrences in the text are highlighted.

For source, we display the abbreviated url for web results. The user can also view the cached version of the page in case the link is temporarily unavailable. This is very similar to typical web search. For book results, the source is the chapter/section headings. The user can also preview the content of the page, assuming the copyright issue has been resolved.

We use the Exhibit framework for displaying a list of results. Exhibit is a framework for web developers to create html pages with dynamic exhibits of data collections. The collections can be searched and browsed using faceted browsing of the search results, based on client-side Javascript. Users can filter the results by resource types, by sites, and/or by keywords. Results can also be grouped together. It provides pagination. Figure ?? shows the detailed view of the faceted search control.

6. EVALUATION

6.1 Screenshot matching performance

We manually captured 50 unique screenshots from Windows, 50 screenshots from Windows Mac. We evaluated among the returned images, how many of them are correct. We used AMT to evaluate the result. Each result is independently reviewed by as least two workers. We only ask them to rate at most top 10. For some screenshot queries, the returned results can be fewer than 10. To prevent the Turkers from cheating, we mixed in one image known to be a match (the query image itself) and two images known to be mismatch (two other query images). The results are shuffled. This setup ensures that the optimal strategy for the workers is to perform tasks honestly. Turker marks each image in the result as match or mismatch. The assignment is approved only if the Turker also correctly identified the ground truth items.

We received X answers. Y of them are approved. The approval rate was X.

6.2 Compare to keyword search

We compare the results to two keyword search baselines. The first baseline is regular web search result. The second baseline is image search result.

For each query instance, we collected the top four results returned by each system for a total of 12 results. We added three known garbage links using only one of the terms. To generate results using keyword search, For example, for "system properties" we used the word "system" to generate results expected to be bad. Workers' were told some of the results were obviously useful and some not useful. Their assignments were approved only if they rated these obvious ones correctly. This setup ensures the optimal strategy is to answer honestly.

We compare each pair of systems. Each subject will perform 100 tasks and paid 10 dollars for their efforts. To generate a pool of results, we pick 25 application windows from XP, 25 from Mac OS. We generate keywords by taking the words from the title of each window. We use these keywords to search Bing Web search and Image search respectively. Since there are three systems, the total number of results are 150. Since we want each result to be evaluated by twice by two subjects, the total number of tasks needed are 600.

At each task, the subject is presented with 10 results by combining the top 5 results returned by each system in the pair. The subject is asked to identify the most and least useful pages. The results are randomly scrambled to remote the bias due to the ordering in the presentation. We will be able to know which system has the most number of results marked as most useful by users.

We use Amazon Mechanical Turk as a proxy of real users. To avoid cheating, after evaluating a result, the subject is asked to evaluate the same result but in a different ordering. The rationale is that if the subject is serious, the subject will likely make the same judgement regarding the usefulness even though they are ordered differently. In other words, the optimal strategy is to work on the task seriously. The subjects can not cheat by guessing. Also, the set will be presented to at least two different subjects. We keep only results that are consistent within and between subjects.

6.3 Comparison to keyword search

6.4 Comparison of several ranking strategies

7. SUMMARY