Intellectual Access to Images

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ABSTRACT

CONVENIENT IMAGE CAPTURE TECHNIQUES, inexpensive storage, and widely available dissemination methods have made digital images a convenient and easily available information format. This increased availability of images is accompanied by a need for solutions to the problems inherent in indexing them for retrieval. Unfortunately, to date, very little information has been available on why users search for images, how they intend to use them, as well as how they pose their queries, though this situation is being remedied as a body of research begins to accumulate. New image indexing methods are also being explored. Traditional concept-based indexing uses controlled vocabulary or natural language to express what an image is or what it is about. Newly developed content-based techniques rely on a pixel-level interpretation of the data content of the image. Concept-based indexing has the advantage of providing a higher-level analysis of the image content but is expensive to implement and suffers from a lack of interindexer consistency due to the subjective nature of image interpretation. Content-based indexing is relatively inexpensive to implement but provides a relatively low level of interpretation of the image except in fairly narrow and applied domains. To date, very little is known about the usefulness of the access provided by content-based systems, and more work needs to be done on user needs and satisfaction with these systems. An examination of a number of image database systems shows

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the range of techniques that have been used to provide intellectual access to image collections.

Introduction

With the rapid development of computing technologies, particularly in storage, display, and telecommunications, access to digital images has become widespread. At the same time, the ease with which images can be incorporated into software packages for display, publication, and dissemination has increased the perceived information need of users for images. This greatly increased need for, and access to, images has focused attention on the problems inherent in image description, particularly from the perspective of image indexing and retrieval. Researchers in the fields of library and information science, computer science, medical informatics, cognitive science, and so on, have brought their different points of view to address the problems inherent in image indexing. The development and use of controlled vocabularies for image indexing has always been an area of interest, and the exploration of natural language for image description is an area of ongoing research. A relatively new research area, drawing on the pixel-level data that comprise digital images, is content-based retrieval, which automatically extracts index features such as color, texture, and shape from the image file. Other researchers are examining the potential of combined sources of evidence using natural language text, such as captions, to assist in the automatic interpretation of digital images. A welcome development in the study of image access is the focus of a number of researchers on questions underlying users' access to images—i.e., how images are perceived and described, what information needs exist, and how users of pictorial information determine what is useful to them. The answers to these questions will inform the design of a new generation of image retrieval systems that will better meet the needs of users by employing technologies in useful and creative ways.

The discussion will focus on the problems inherent in image description and access, with a perspective on traditional and new solutions. Recent developments in intellectual access to images will be surveyed and contrasted with software-based analysis of image content. A more detailed survey of this research is given by Rasmussen (1997). Lancaster (1998) extends the discussion of indexing to multimedia sources.

Challenges in Image Indexing

Images bring with them problems of description and access more complex than those of text. While text can be indexed manually, it can also be retrieved directly using, as access points, the natural language that it contains. While this retrieval is imperfect, it does provide a means of access independent of human indexing. Digital images are composed of pixels arranged in an infinite variety of patterns and, in general, it is im-

possible to predict the particular pattern that would match an information need. At present, only relatively low-level attributes of images can be queried directly (for instance, color and texture), and these attributes do not carry the meaning of the image with them.

Even where human indexing of the image is undertaken, it is difficult to reach agreement on the content and meaning of the image, or on what aspects are appropriate for indexing. The same image may mean different things to different people and may be used to project a different meaning at different times depending on the way it is used or the aspect that is the focus of attention or the context it is chosen to illustrate.

In general, it is easier to determine a picture's content than to interpret what it is about, and this distinction has engaged many scholars. Krause (1998) distinguishes between "hard" indexing (the description of what an indexer can see in the frame), and "soft" indexing ("aboutness," the image as stimulus). He says:

> We know that pictures provoke reaction, stimulate ideas, rekindle memories. They are powerful instruments in story telling, teaching, propaganda, and numerous other fields. Therefore, it is important that libraries provide access to images which illustrate ideas, even abstract ones like hunger, or the experience of hunger .... If we can index this aspect of the picture, we make it easily available to users requiring such an image; we make our collection more accessible. (pp. 73-74)

A number of authors (such as Shatford, 1986) have based their analysis of image indexing on the theories of the art historian Panofsky (1939), who identified three levels of meaning in works of art. At the first, or pre-iconographic, level, subject matter was designated as factual ("ofness") or expressional ("aboutness"), and based on the objects and events in an image as it could be interpreted through everyday experience. At the second, or iconographic, level, interpretation requires some cultural knowledge of themes and concepts (not "a sailor" but "Ulysses"). The third or iconological level requires interpretation at a sophisticated level using world and cultural knowledge plus a deeper understanding of the history and background of the work. Shatford (1986) suggests that this third level cannot be indexed with any degree of consistency. Svenonius (1994) points out that "indexing aboutness at the iconographic level is equally problematic" (p. 603), since what is symbolized is not always evident, nor is there always a simple referent to it.

Shatford (1986) uses Panofsky's levels of meaning to explore the kinds of subjects an image might have, proposing "Generic Of," "Specific Of," and "About" with facets answering the questions Who? What? When? and Where? Interestingly, a preliminary attempt in the Hulton study (described later in this article) to categorize queries posed to an image database according to Panofsky's levels of meaning was not successful, suggesting that

they did not translate well from the area of Renaissance art to a more general domain (Enser & McGregor, 1993).

Markey (1984) studied interindexer consistency by nonspecialists using a free vocabulary to index pictorial works of art, finding terminology consistency scores of 7 percent and concept consistency scores of 13 percent. While interindexer consistency has always been problematic, even in text, these figures do serve to illustrate the imperfect level of agreement in subject analysis of images. Clearly, image analysis can be carried out at many levels, from the primitive (What colors are present? What shapes?) to more analytical but general (What objects appear in the image? What is this a picture of?) to a more culturally dependent interpretation (What specific individual or thing is portrayed? What is the mood? What metaphor or lesson is presented?). Choosing an approach to image indexing may require a compromise based on what the system is capable of delivering and what the users of the system would like in an optimal retrieval environment. The question of user need for images is at present relatively little studied.

Studies of Users' Image Queries

Before considering how image access has been provided, it is worth considering what we know about users' information needs and how users present queries to image databases. Probably the most extensive study to address this question is the "Hulton Study," Enser and McGregor's (1993) examination of the queries addressed to the Hulton Deutsch picture collection. The Hulton Deutsch Collection is a major picture archive of news and current affairs, historical landscapes and portraits, and other collections used primarily by the press. Enser and McGregor examined 2,722 requests and found that they could be mapped into four categories along two dimensions: unique ("Kenilworth Castle") or non-unique ("dinosaurs") and refined (e.g., specified by activity, time period, and so on) or nonrefined. An example of a query in the unique refined category is "Edward VIII looking stupid" and in the nonunique refined category is "couples dancing the Charleston." Interestingly, only requests for unique unrefined subjects were easily satisfied by the Gibbs-Smith classification scheme being used by the picture archive (Enser, 1995). The Hulton Study was subsequently extended to seven additional picture libraries/archives in the United Kingdom, five of which were concerned with still images (Armitage & Enser, 1997). They arrived at a mode and facet analysis adopted from Panofsky (1939) and refined by Shatford (1986).

In a smaller-scale study, Hastings (1995) examined the queries of a specific user group—i.e., art historians—to a collection of Caribbean art images. She identified queries at four levels of complexity, ranging from simple level one queries for who, what, where to level four queries for meaning, subject, and why? Some of the simpler queries could be an-

swered without images while, at the most complex level, text and image alone was sometimes not sufficient to answer the queries.

Another interesting study reviewed queries presented to NLM's Prints and Photographs Collection. Keister (1994) found that descriptions of concrete image elements made up a significant proportion of picture requests, and these elements were worth cataloging in some detail. However, she cites examples in which images are described in terms of the visual message of the picture—e.g., a "warm picture of a nurse, mother, and baby" (p. 10). Word-images based on a particular communication need arose frequently, and users often described and used images in ways different from their original intent.

While there begins to be a body of research addressing the question of image information needs, the studies are fragmented. The Hulton Study remains the only study of its scale to examine information needs in a nondomain-specific environment.

Image Attributes

There is as yet no general agreement on what attributes of an image should be indexed. Shatford (1986) indicates that it is much easier to index an image for a collection with some specific use than one for use by a heterogeneous group. In the latter case, the subject orientation of users and the information need that will lead them to pose queries to the collection cannot be anticipated, and hence the dimensions along which the collection should be indexed cannot be predicted.

Research by Jorgensen (1998), in which participants were asked to write descriptions of color images, suggested four perceptual classes as a minimal framework for image indexing: objects (the largest set in her study), people, color, and location. Content/story attributes were also identified as significant for image description. Jorgensen (1998) points out the need to include interpretive as well as perceptual attributes, a conclusion supported by her previous research (1995). She indicates that "the disjunction between these results and those attributes typically addressed in traditional image indexing systems suggest revisiting assumptions upon which image indexing and retrieval systems are being created" (p. 172).

In order to determine what image attributes should be used to provide access, Layne (1994) proposes four categories: (1) "biographical" attributes that deal with the images' origin and provenance; (2) subject attributes (the "most problematic and least objective" [p. 584]); (3) exemplified attributes that seem to be physical characteristics such as medium, and (4) relationship attributes (relationship to other images or texts). It is the subject attributes which are addressed here; the two main approaches to image indexing, concept-based and content-based, differ in the level of interpretation that they bring to the indexing process and will be discussed separately.

Concept-Based Image Indexing and Retrieval

Concept-based retrieval refers to retrieval from text-based indexing of images, which may use a controlled vocabulary or natural language text or captions, and range from the purely descriptive ("Winston Churchill," "a duck on a pond") to the abstract or subjective ("poverty," "despair").

Controlled vocabularies have been developed for use in specific collections such as Western art or images of historical costume. A particularly ambitious undertaking is ICONCLASS, an early classification system for Western art developed in the 1940s by van de Waal at the University of Leiden. Nine areas are covered: (1) Religion, Magic and the Supernatural; (2) Nature; (3) Man (as a biological entity); (4) Society, Civilization, and Culture; (5) Abstract Concepts; (6) History; (7) The Bible; (8) Non-Classical Myths, Tales and Legends; and (9) Classical Mythology and History (Sherman, 1987). These subjects are subdivided using an alphanumeric notation covered in seven volumes of subject headings. ICONCLASS has been used for DIAL (Decimal Index to the Art of the Lowlands), the Marburger Index to works of art in Germany, van Straten's index of Italian Prints, and American paintings in the Courtauld Institute (Roberts, 1988).

Two controlled vocabularies that were developed relatively recently are the *Art & Architecture Thesaurus* (*AAT*) (Oxford University Press, 1990) and the Library of Congress *Thesaurus for Graphic Materials* (Library of Congress, 1995). The *Art & Architecture Thesaurus (AAT)* covers the history and making of the visual arts and is geographically and historically comprehensive but lacks coverage of iconographical themes (Petersen, 1990). The vocabulary of nearly 120,000 terms is structured under seven facets (e.g., physical attributes, styles and periods, activities) which are subdivided into thirty-three sub-facets or hierarchies. It is currently supported by the Getty Information Institute (see their Web page at http://www.gii.getty.edu/vocabulary/aat.html).

The *Thesaurus for Graphic Materials* is in two parts: *TGMI: Subject Terms* and *TGMII: Genre and Physical Characteristic Terms*. *TGMI* is less structured than *AAT*, lacking its faceted and highly hierarchical arrangement, though it does follow standard thesaural guidelines. *TGMI* provides a broader, though smaller, vocabulary than *AAT*, suitable for a general subject description of images. A detailed comparison of these two vocabularies is provided by Greenberg (1993).

Other controlled vocabularies have been developed for specific collections but, for many collections of images, particularly those on the Web, natural language indexing is preferred. Natural language may be in the form of text in which the image is embedded (newsphotos in newspapers, for instance), descriptions or captions accompanying it, or hypermedia links. For instance, Guglielmo and Rowe (1996) used natural language requests to query a database of historical images of aircraft and weapon

projects captioned with natural language text. By parsing and matching queries and captions, they were able to use natural language processing and inferencing techniques to answer queries such as "training missiles on a skyhawk."

In some contexts it seems logical to use images as surrogates for text in retrieval. A project at NASA's Johnson Space Center used a visual thesaurus to provide access to images from the Manned Space Flight Program, using images corresponding to those in a subject-oriented linguistic thesaurus (Seloff, 1990). This and other examples of visual thesauri are discussed by Hogan et al. (1991), who extend the concept of the visual thesaurus to the hypermedia environment, supporting browsing and searching through direct image links. This type of access corresponds to what Enser (1995) refers to as image retrieval in the VV mode—visual query, visual search.

Content-Based Indexing of Images

Content-based information retrieval (CBIR) refers to retrieval based on computer analysis of image content at the pixel level, automatically extracting such features as color, texture, and shape, locally or globally, from digital images. The CBIR systems currently available provide powerful retrieval engines for certain classes of query, although the developers have sometimes oversold their abilities, arguing that, since human indexing of image subject is prohibitively expensive, they propose to replace it by automatic indexing by color and texture. These systems are useful in some situations and no doubt will become more useful as their powers of interpretation become more sophisticated. The query categories proposed for them by Gudivada and Raghavan (1995) are color, texture, sketch, shape, volume, spatial constraints, browsing, objective attributes, subjective attributes, motion, text, and domain categories. Perhaps the capabilities that are currently best developed are retrieval by color, texture, and overall image similarity. Shape retrieval is most effective where solid images (clip art, trademarks) are queried. Domains where automatic indexing and retrieval have proven effective include face retrieval and fingerprints.

A realistic assessment of the state of the art of what they name visual information retrieval (VIR) is given by Gupta and Jain (1997). They indicate that systems providing information extraction from images still require some human image interpretation. The relative merits of concept- and content-based indexing are weighed by Flickner et al. (1995):

> Perceptual organization—the process of grouping image features into meaningful objects and attaching semantic descriptions to scenes through model matching—is an unsolved problem in image understanding. Humans are much better than computers at extracting semantic descriptions from pictures. Computers, however, are better

> than humans at measuring properties and retaining these in long-term memory. (p. 23)

Probably the best known such system, the Query by Image Content (QBIC) system developed by IBM, is commercially available and widely used (Flickner et al., 1995) (http://www.qbic.almaden.ibm.com). Image features are automatically extracted and stored in a database. Because of the problems in automatically outlining objects, manual and user-assisted techniques are used to identify shapes, though automated methods are available in some domains. Queries, which may be color and texture, user-drawn outlines, or sample images, are posed by sketching, selecting from a color palette, or selecting an image from a retrieved set as a further query. The QBIC system is currently being tested by the Department of Art and Art History at the University of California at Davis (Holt & Hartwick, 1994; Holt et al., 1997). They report better success with color and texture searches than with shape for content-based retrieval, with text searches preferred when artist or image is already known. Other similar systems include Virage (http://www.virage.com) and VisualSEEK (http://www.ctr.columbia.edu/~jrsmith/VisualSEEK/).

One of the more interesting developments in image indexing is the integration of concept- and content-based approaches using the information in descriptive text or captions to assist in the interpretation of the image. For instance, work by Srihari (1995) examines retrieval from a database of captioned newspaper photographs. Captions place constraints on the photographs, which help in identifying their content and the location in the image of the objects or individuals; however this information can often be interpreted only in the context of world knowledge, since human viewers are expected to recognize, for instance, President Clinton, or differentiate between Mr. and Mrs. Smith without spatial information. For example, it is hard to imagine the need for a caption as specific as "President Clinton (left) dancing with Hillary Clinton (right) at the Inaugural Ball." Research on the combination of textual and image sources of evidence for retrieval holds some promise in overcoming some of the disadvantages of text or image-based retrieval alone.

Image Indexing Environments—Case Studies

An examination of image collections on the WWW shows that it is not uncommon for access to be limited to a simple browsing approach. However, there are many collections in which indexing was used to improve access, either through a concept- or content-based technique. A few case studies will serve to illustrate the range of solutions that have been applied.

The Promenade system (McLean et al., 1994) was designed to provide access to a series of botanical images published in *Curtis Botanical Magazine*, an eighteenth-century compilation of images and text describ-

ing botanical samples collected by captains on voyages of exploration. The original intent was to use the natural language text of the descriptions as the index information, but the early printing, irregular typefaces, and nonstandard abbreviations made the text error-prone for OCR or human transcription, and a vocabulary and procedures for human indexing were selected. Since no existing vocabulary seemed well-suited to the historical and botanical nature of the image and textual materials, one was tailored to the image collection. This was an expensive solution, and the project could have benefited from content-based indexing techniques, then in their infancy, since retrieval by color was significant, and the clearly delineated botanical images would have allowed some degree of shape matching.

Two image database projects using controlled vocabulary are ELISE and Déjà Vu. The ELISE Project, funded by the European Commission, provides retrieval of full color images over a network (Black & Eyre, 1995). Initially two image collections, one from the Victoria and Albert Museum and one from Tilburg University Library in the Netherlands, were made available using both full-text descriptions and controlled vocabulary with the *AAT* as the source. Déjà Vu is an interface created for information retrieval systems in which users can browse through subject terms to find items that meet their information needs. The browsing process is facilitated by a knowledge structure in which subject terms are grouped based on the commonsense knowledge of library users in order to provide an interconnected browsing space. For example, when a user enters a search statement, the Broader Terms (BT), Narrower Terms (NT), Related Terms (RT), Notes, some relevant knowledge, and retrieved items will be displayed. The authors used the Library of Congress *Thesaurus for Graphic Materials* in this project (Gordon & Domeshek, 1998).

One of the more interesting applications of content-based retrieval systems is to databases of trademarks. While shape-based retrieval can be problematic in fine arts images with complex patterns of light and dark which make it difficult to extract individual shapes, trademarks are generally high-contrast shapes with good definition. The STAR system for trademark archiving and registration (Wu et al., 1995) is intended to allow searches for conflicting trademarks when a request is made for registration of a new image. The system ranks retrieved trademarks in order of similarity to the query trademark.

There are a number of instances on the Web of databases that are searchable using the QBIC software. For example, the Fine Arts Museum of San Francisco offers a QBIC search of a portion of its database comprising 3,000 Japanese prints. The similarity measure may be based on color percentages, color layout, texture, or a search may be customized using a color palette indicating the percentages desired of up to five colors (see their Web site at http://www.thinker.org/imagebase/index-2.html). IBM

offers demonstration searches of stamps, trademarks, and stock photos at their site at http://www.qbic.almaden.ibm.com/. The University of California at Davis study discussed above (Holt & Hartwick, 1994; Holt et al., 1997) can also be explored on their Web site at http://libra.ucdavis.edu/qbic.html.

Reports of the evaluation of image access systems are relatively rare in the literature. An exception is an evaluation of the Micro Gallery, a visitor information system at the National Gallery in London by Beaulieu and Mellor (1995). The system allows museum visitors to search the gallery collection by artist, historical atlas, picture type, and general reference. A combination of data collection methods was used to examine the impact of the interface features on search behavior, including questionnaires before and after the use of the system and direct observation with a talk aloud protocol.

Conclusion

With the increased availability of images comes the problems inherent in indexing them for retrieval. In order to develop solutions to these problems, more information is needed on why users search for images and how they intend to use them as well as how they pose their queries. Two approaches to image indexing have been developed and studied—concept-based and content-based. Concept-based indexing has the advantage of providing a higher-level analysis of the image content but is expensive to implement and suffers from a lack of interindexer consistency due to the subjective nature of image interpretation. Content-based indexing is relatively inexpensive to implement but provides a relatively low level of interpretation of the image except in fairly narrow and applied domains. To date, very little is known about the usefulness of the access provided by content-based systems, and more work needs to be done on user needs and satisfaction with these systems. An examination of a number of image database systems shows the range of techniques that have been used to provide intellectual access to image collections.

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