Content-Based Image Retrieval Systems

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***Abstract**: In this paper we present image data representation, similarity image retrieval, the architecture of a generic content-based image retrieval system, and different content-based image retrieval systems.*

***Key words:** Image, Image Analysis, Image Retrieval, Image Databases*

INTRODUCTION

Visual information systems are radically different from conventional information systems. Many novel issues need to be addressed. A visual information system should be capable of providing access to the content of pictures and videos. Where symbolic and numerical information are identical in content and form, pictures require a delicate treatment to approach their content. To search and retrieve items on the basis of their pictorial content requires a new visual way of specifying the query, new indices to order the data and new ways to establish similarity between the query and the target. A major problem stems from the fact that an interpretation of an image has no unique meaning. Contextual information and knowledge of the world is essential to deliver an interpretation of the picture [1].

A number of keyword-based general WWW search engines allow work with images (HotBot (http://hotbot.lycos.com/), and NBCi (http://www.nci.com/)). A number of other general search engines are more specially for images, such as Yahoo!'s Image Surfer (http://isurf.yahoo.com/) other multimedia searcher of Lycos (http://multimedia.lycos.com/), but they are still only keyword based.

The main problems by dealing with Content-Based Image Retrieval Systems are image data representation and similarity image retrieval.

IMAGE DATA REPRESENTATION

The image data can be treated as a physical image representation and their meaning as a logical image representation [6, 7, 19]. The logical representation includes the description of the image, image-objects characteristics, and the relationships among the image objects.

Physical Image Representation

The most common form of the physical image representation is the ***raster form***. The raster form includes the image header and image matrix. The ***image header*** describes the main image parameters such as image format, image resolution, number of bits per pixel, and compression information. The ***image matrix*** contains the image data.

Logical Image Representation

An ***image object*** is either an entire image or some other meaningful portion (consisting of a union of one or more disjoint regions) of an image, which we have called a ***semcon***. The image description includes meta, semantic, color, texture, shape, and spatial attributes. In 2-D space, many of the image features can be represented as sets of points. These points can be tagged with labels to capture any necessary semantics. Each of the individual points representing some feature of an image object we call a ***feature point.***

Meta-attributes are attributes related to the process of the image creation. These attributes can be image acquisition date, image identification number and name, image modality device, image magnification, etc.

Semantic attributes contain subjective information about the analyzed image. A specialist in the field of the specific image collection gives the values of such attributes.

***Color attribute*s** could be represented as a histogram of intensity of the pixel colors. Based on a fixed partition of the image, an image could be indexed by the color of the whole image and a set of inter-hierarchical distances, which encode the spatial color information. The system Color-WISE described in [18] partitions an image into 8*8 blocks with each block indexed by its dominant hue and saturation values. A histogram refinement technique is described in [17] by partitioning histogram bins based on the spatial coherence of pixels. A pixel is coherent if it is a part of some sizable similar-colored region, and incoherent otherwise.

Texture attributes. According to Amadasun and King [2]: "Literally, texture refers to the arrangement of the basic constituents of a material. In the digital image, texture is depicted by the spatial interrelationships between, and/or spatial arrangement of the image pixels". The most used set of texture features is Haralick's gray level co-occurrence features [10]. Other often-used texture measurements are (1) Tamura features [21]. He suggested six basic textural features: coarseness, contrast, directionality, line-likeness, regularity, and roughness; (2) Unser's sum and difference histogram [22]. He proposed 32 features based on calculations over different sums and histograms of the pixel gray levels; (3) Galloway's run-length based features [5]. He calculated 20 coefficients on the basic on run-length matrixes; (4) Chen's geometric features form binary image sequences [4]. He proposed 16 coefficients, based on threshold images; (5) Laine's texture energy from Daubechies wavelet [13]. He suggested 21 features, based on Daubechies wavelet transformed image. Wagner [24] summarized 18 methods including 318 different features.

Shape attributes techniques can be represented in two distinct categories: ***measurement-based methods*** ranging from simple, primitive measures such as ***area*** and ***circularity*** to the more sophisticated measures of various ***moment invariants***; and ***transformation-based methods*** ranging from functional transformations such as ***Fourier descriptors*** to structural transformations such as ***chain codes*** [15] and ***curvature scale space feature vectors***. An attempt to compare the various shape representation schemes is made in [16]. Those features, which characterize the shape of any image object, can be classified into the following two categories. ***Global shape features*** are general in nature and depend on the characteristics of the entire image object. ***Area, perimeter,*** and ***major axis*** direction of the corresponding image region are examples of such features. ***Local shape features*** are based on the low-level characteristics of image objects. The determination of local features usually requires more involved computation. ***Curvatures, boundary segments,*** and ***corner points*** around the boundary of the corresponding image region are examples of such features.

Spatial attributes could be presented in different ways: (1) as a ***topological set of relations*** between two image-objects, containing the relations *in, disjoint, touch,* and *cross;* (2) as a ***vector set of relations*** which considers the relevant positions of the image-objects. These include E, S, W, N, SE, SW, NW, NE in terms of the four world directions East, South, West, North; (3) as a ***metric set of relations*** based on the distance between the image-objects, containing the relations *close, far, very close, very far;* (4) ***2D-strings*** [3]. Each image is considered as a matrix of symbols, where each symbol corresponds to an image object. The corresponding 2D-string is obtained by symbolic projection of these symbols along the horizontal and vertical axes, preserving the relative positions of the image objects. In order to improve the performance of this technique, some 2D-string variants have been proposed, such as the extended 2D-string [12], 2D C-string [14], and 2D C^+-string [11]; (5) geometry-based ***θR-string***

approach [9]; (6) the ***spatial orientation graph*** [8], (7) the ***quadtree-based spatial arrangements of feature points*** approach [1].

SIMILARITY RETRIEVAL

Let a query be converted in an image description $Q(q_1, q_2, \ldots, q_n)$ and an image in the image database has the description $I(x_1, x_2, \ldots, x_n)$. Then the retrieval value (RV) between Q and I can be defined as: $RV_Q(I) = \Sigma_{i = 1, \ldots, n} (w_i * sim(q_i, x_i))$, where w_i $(i = 1,2, \ldots, n)$ is the weight specifying the importance of the i^{th} parameter in the image description and $sim(q_i, x_i)$ is the similarity between the i^{th} parameter of the query image and database image and is calculated in the different way depending if q_i, x_i are ***symbol, numerical***, ***linguistic*** **values**, ***histograms***, ***attribute relational graphs*** or ***pictures*** [20].

ARCHITECTURE OF A CONTENT-BASED IMAGE RETRIEVAL SYSTEM

The architecture of a generic content-based image retrieval system is given in Fig. 1. Three phases for interaction with the system are provided: domain definition, image entering, and image retrieval. The domain definition phase is used by the administrator to introduce new application areas for the system. At the second phase the images are entered into the system. The third phase is image retrieval. In it the end-users use the system for posing queries and viewing the image features of the result image subset.

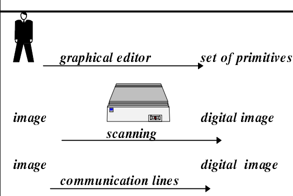
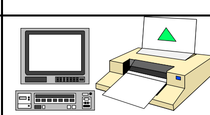
PHASE	INPUT	PROCESS	RESULT
1.Domain definition			
a. logical description	Logical Image Definition Language (LIDL)	LIDL processor	procedure for image indexing
b. physical description	Physical Image Definition Language (PIDL)	PIDL processor	procedure for physical image storage
2. Storage			
a. input the image and image information		Image Storage Language (ISL) processor	logical and physical IDB
b. image updating	ISL updating tools	ISL processor	logical and physical IDB
c. image deletion	ISL deletion tools	ISL processor	logical and physical IDB
3. Image retrieval			
a. image display	Image Manipulation Language (IML)	Query processor	
b. logical image display	IML	Query processor & Statistical processor	semantic data statistical data

Fig. 1. Generic architecture of a content-based image retrieval system

CONTENT-BASED IMAGE RETRIEVAL SYSTEMS

A number of valuable content-based image retrieval systems, presented in alphabetical order are:

1. ADL (Alexandria Digital Library). Developer University of California, Santa Barbara. URL http://www.alexandria.ucsb.edu/adl.html.
2. Amore (Advanced Multimedia Oriented Retrieval Engine). Developer C & C Research Laboratories NEC USA, Inc. URL http://www.ccrl.com/amore/.
3. Berkeley Digital Library Project. Developer University of California, Berkeley. URL http://elib.cs.berkeley.edu/
4. Blobworld. Developer Computer Science Division, University of California, Berkeley. URL http://elib.cs.berkeley.edu/photos/blobworld/.
5. CANDID (Comparison Algorithm for Navigating Digital Image Databases). Developer Computer Research and Applications Group, Los Alamos National Laboratory, USA. URL http://public.lanl.gov/kelly/CANDID/index.shtml.
6. C-bird (Content-Based Image Retrieval from Digital libraries). Developer School of Computing Science, Simon Fraser University, Burnaby, B.C., Canada. URL http://jupiter.cs.sfu.ca/cbird/
7. Chabot. Developer Department of Computer Science, University of California, Berkeley, CA, USA. URL http://http.cs.berkeley.edu/~ginger/chabot.html.
8. CBVQ (Content-Based Visual Query). Developer Image and Advanced Television Lab, Columbia University, NY. URL http://maya.ctr.columbia.edu:8088/cbvq/.
9. DrawSearch. Developer Department of Electrical and Electronic Engineering, Technical University of Bari, Italy. URL http://deecom03.poliba.it/DrawSearch/DrawSearch.html.
10. Excalibur Visual RetrievalWare. Developer Excalibur Technologies. URL http://vrw.excalib.com/.
11. FIR (Formula Image Retrieval). Developer Developed by Fraunhofer Institute for Computer Graphics, Darmstadt, Germany, in association with Txt Ingegneria Informatica S.P.A. (Italy), Giunti Multimedia Srl (Italy), EpsilonSoftware (Greece), and Kino TV & Movie Productions S.A. (Greece), as part of the Esprit IV project FORMULA. URL http://www.igd.fhg.de/igd-a7/projects/formula/formula_e.html
12. FOCUS (Fast Object Color-based Query System). Developer Department of Computer Science, University of Massachusetts, Amherst, MA. URL http://wagga.cs.umass.edu/~mdas/color_proj.html.
13. ImageFinder. Developer Attrasoft Inc. URL http://attrasoft.com/abm3_4.html.
14. ImageMiner. Developer Technologie-Zentrum Informatik, University of Bremen, Germany. URL http://www.tzi.de/bv/ImageMinerhtml/.
15. ImageRETRO (Image RETrieval by Reduction and Overview). Developer Department of Computer Science, University of Amsterdam, The Netherlands. URL http://carol.wins.uva.nl/~vendrig/imageretro/.
16. ImageRover. Developer Department of Computer Science, Boston University, MA. URL http://www.cs.bu.edu/groups/ivc/ImageRover/.
17. ImageScape. Developer Department of Computer Science, Leiden University, The Netherlands. URL http://www.wi.leidenuniv.nl/home/lim/image.scape.html.
18. MARS (Multimedia Analysis and Retrieval System). Developer Department of Computer Science, University of Illinois at Urbana-Champaign. URL http://www-db.ics.uci.edu/pages/research/mars.shtml.
19. MetaSEEk. Developer Image and Advanced Television Lab, Columbia University, NY, USA. URL http://www.ctr.columbia.edu/metaseek/.

20. Photobook. Developer Vision and Modeling Group, MIT Media Laboratory, Cambridge, MA. URL http://vismod.www.media.mit.edu/vismod/demos/photobook/index.html.
21. PicToSeek. Developer Department of Computer Science, University of Amsterdam, The Netherlands. URL http://www.science.uva.nl/research/isis/pictoseek/.
22. QBIC (Query By Image Content). Developer IBM Almaden Research Center, San Jose, CA. URL http://wwwqbic.almaden.ibm.com/.
23. VisualSEEk. Developer Image and Advanced Television Lab, Columbia University, NY. URL http://www.ctr.columbia.edu/VisualSEEk/.
24. WebSEEk. Developer Image and Advanced Television Lab, Columbia University, NY. URL http://www.ctr.columbia.edu/WebSEEk/.

CONCLUSIONS

Most content-based image retrieval systems are products of research, and therefore emphasize one aspect of content-based retrieval [23]. Most systems use color and texture features, few systems use shape feature, and still less use spatial features. The retrieval on color usually yields images with similar colors. Retrieval on texture does not always yield images that have clearly the same texture, unless the database contains many images with a dominant texture. Searching on shape gives sometime surprising results. The larger the collection of images, the more chance that it contains an image similar to the query image. The Web is a large enough test set, and free of charge. It is widely recognized that most current content-based image retrieval systems work with low level features (color, texture, shape, spatial), and that next generation systems should operate at a higher semantic level.

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