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Current State and Research Trend in the Image Database Systems

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There is a lot of work going on the field of image database systems. Searching for the term "image databases" in the "Google" search engine we received 32 700 documents, in the "Alta vista" search engine – 23 100 documents, in the "Yahoo" search engine – 23 400 documents. In this paper we discuss the current state and the research trend in the area of the image database systems.

1. Images. Let us start with the word "image". The surrounding world is composed of images. Humans are using their eyes, containing 1.5 x 10^8 sensors, to obtaining images from the surrounding word in the visible portion of the electromagnetic spectrum (wavelengths between 400 and 700 nanometers). The light changes on the retina are sent to the image processor center in the cortex.

The human vision is qualitative and comparative rather than quantitative. There are experiments suggesting that human are especially poor at judging color or brightness. Usually only object boundaries and elementary structures in the view are extracted from the scene and processed by the human image processing system. This is the reason for variety of visual illusions.

Telescopes and microscopes allow seeing things that are too small or too large than the humans could see otherwise. Video cameras are devises that are used frequently to acquire and store images from the surrounding word. Instead of light gray scale brightness radio intensity is used in radio telescope image, acoustic waves in acoustic microscope, electron diffraction pattern in electron microscope, water sell relaxation times in the magnetic resonance images, etc.

In the image database systems geographical maps, pictures, medical images, pictures in medical atlases, pictures obtaining by cameras, microscopes, telescopes, video cameras, paintings, drawings and architectures plans, drawings of industrial parts, space images are considered as images.

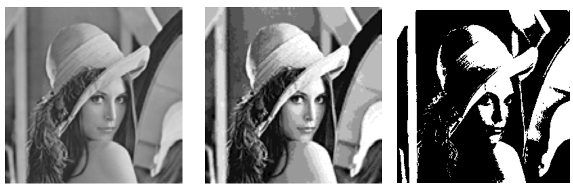
There are different models for color image representation. In the seventeen century Sir Isaac Newton showed that a beam of sunlight passing through a glass prism comes into view as a rainbow of colors. Therefore, he first understood that the white light is composed of many colors. Typically, the computer screen can display 2^8 or 256 different shades of gray. For color images this makes $2^{3 \times 8}$ = 16 777 216 different colors. Combining red and green produces yellow, green and blue - cyan, blue and red yellow. Cyan, yellow and managenta are the primitives used in printing.

Clerk Maxwell showed in the late nineteen century that every color image cough be created using three images - Red, Green and Blue image. A mix of these three images can produce every color. This model, named RGB model, is primarily used in image representation. The RGB image could be presented as a triple (R, G, B) where usually R, G, and B take values in the range [0, 255]. Another color model is the YIQ model (lumination (Y), phase (I), quadrature phase (Q)). It is the base for the color television standard.

Images are presented in computers as a matrix of pixels. They have finite area. If we decrease of the pixel dimensions the pixel brightness will become close to the real brightness. The same image with different pixel dimensions is shown below.

The Lena image with 256 by 256, 128 by 128, 64 by 64, 32 by 32, 16 by 16, 8 by 8, and 4 by 4 pixels

The same image, with different number of used gray levels is given below.



The Lena image with 256, 16, and 2 gray levels

2. Image Database Systems. Set of images are collected, analyzed and stored in multimedia information systems, office systems, Geographical Information Systems (GIS), robotics systems, CAD/CAM systems, earth resources systems, medical databases, virtual reality systems, information retrieval systems, art gallery and museum catalogues, animal and plants atlases, sky star maps, meteorological maps, catalogues in shops and many other places. The first survey in the field on image databases is [9]. Excelled papers about the development of the image databases are [1, 3, and 4].

There are sets of international organizations dealing with different aspects of image storage, analysis and retrieval. Some of them are: AIA (Automated Imaging/Machine Vision - www.robotics.org), AIIM (Document Imaging - www.aiim.org), ASPRES (Remote Sensing/Protogram - www.asprg/asprs), DIMA (Digital Photo Marketing - www.pmai.org/dima.htm), DPIA (Digital Printing & Imaging - www.dpia.org), IEEE (Electrical/electronic engineering - www.ieee.org), IS&T (Digital photo/print science & tech - www.imaging.org), SIGGRAPH/ACM (graphics, animation/visualization - www.siggraph.org), SMPTE (Video engineering - www.smpte.org), SPIE (Optical/electro-optical imaging - www.spie.org), XPLOR (Document Create/Distribute - www.xplot.org). There are also many international centers storing images such as: Advanced Imaging (www.epm.ornl/~batsell/imaging.html), Scientific/Industrial Imaging (www. precissionimages.com), Microscopy Imaging (www.mwrn.com), Industrial Imaging (www.cs.cmu.edu), Satellite Imaging (www.ciesin.org), and Graphic Art (www.phoenix.net). There are also different international work groups working in the field of image compression, TV images, office documents, medical images, industrial images, multimedia images, graphical images, etc.

In many areas of commerce, government, academia, and hospitals, large collections of digital images are being created. Many of these collections are the product of digitizing existing collections of analogue photographs, diagrams, drawings, paintings and prints. Usually, the only way of searching these collections is by keyword indexing, or simply by browsing. Digital image databases however open the way to content-based searching. A number of keyword-based general WWW search engines allow indicating that the search media type is images such as HotBot (http://hotbot.lycos.com/), and NBCi (http://www.nci.com/). A number of other general search engines are specialized in image searching, such as Yahoo!'s Image Surfer (http://isurf.yahoo.com/). The other only keyword based multimedia search engine is Lycos (http://multimedia.lycos.com/). There are many special image collections on the web that can be searched with a number of alphanumerical keys. For example, ImageFinder (http://sunsite.berkeley.edu/ImageFinder/) provides a list of such collections as a tool to help teachers locate historical photographs from collections around the world. AltaVista is a search engine that allows content-based image retrieval, both from special collections, and from the Web. In the last few years, huge image collections have been produced, using such technologies as QuickTime® VR and VRML. Such collections present a new challenge to image management systems, as it is now possible to match image content on their shape. Of course, to work efficiently, to be able to adapt to changing requirements, and to be user friendly, image management systems should have an extensible web-enabled database management system as a backend.

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: 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). 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, 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/.

3. Logical Image Representation in the Image Database Systems. The logical image representation in image databases systems is based on different image data models [2, 5, and 8]. 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. The logical image description includes: meta, semantic, color, texture, shape, and spatial attributes.

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 attributes could be represented as a histogram of intensity of the pixel colors. A histogram refinement technique is also used by partitioning histogram bins based on the spatial coherence of pixels. Statistical methods are also proposed to index an image by color correlograms, which is actually a table containing color pairs, where the *k*-th entry for <*i*, *j*> specifies the probability of locating a pixel of color *j* at a distance *k* from a pixel of color *i* in the image.

Texture attributes. The most used set of texture features is the Haralick's gray level co-occurrence features. Other often-used texture measurements are: (1) Tamura features. He suggested six basic textural features namely coarseness, contrast, directionality, line-likeness, regularity, and roughness; (2) Unser's sum and difference histogram. He proposed 32 features based on calculation on different sums and histograms on the gray level; (3) Galloway's run-length based features. He calculated

20 coefficients on the basic on run-length matrixes; (4) Chens geometric features form binary image sequences. He proposed 16 coefficients, based on threshold images. Wagner summarized 18 different methods included 318 different features and gave the exact formulas for every single texture feature.

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 and curvature scale space feature vectors. Other classification into the following two categories is also well recognized. 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 topological set of relations between two image-objects and contains: in, disjoint, touch, and cross; (2) vector set of relations considers the relevant position of the image-objects: E, S, W, N, SE, SW, NW, NE in terms with the four world directions East, South, West, North; (3) metric set of relations based on the distance between the image-objects and contains: close, far, very close, very far; (4) 2D-strings. 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, 2D C-string, and 2D C^+-string; (5) geometry-based θR-string approach; (6) the spatial orientation graph, (7) the quadtree-based spatial arrangements of feature points approach.

4. Research Trends in the Image Database Systems. An excellent survey in this area is [10]. Most image database systems are products of research, and therefore emphasize only one aspect of content-based retrieval. Sometimes this is the sketching capability in the user interface; sometimes it is a new indexing data structure, etc. Some systems are created as a research version and a commercial product. The commercial version is usually less advanced, and shows more standard searching capabilities. A number of systems provide a user interface that allows more powerful query formulation than is useful in the demo system. Most systems use color and texture features, few systems use shape features, and yet less use spatial features. The retrieval on color usually yields images with similar colors. Retrieval on texture does not always yield images that have similar texture, unless the database contains many images with a dominant texture. Shape searching returns often surprising results. The larger the collection of images, the greater is the chance that it contains an image similar to the query image. Valuable methods for image indexing can be found in [6, 7].

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Съвременно състояние и научни тенденции в развитието на системи бази от изображения

Научната област "Бази от изображения" е една от най-интензивно развиващата се в момента. Ако потърсиме за термина "Бази от изображения" в търсачката "Google" ще открием 32 700 документа, в "Alta vista" – 23 100 документа, в "Yahoo" – 23 400 документа. В тази работа ние дискутираме съвременното състояние и научните тенденции в развитието на базите от изображения.