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SOFIA: An Image Database with Image Retrieval by Image Content

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In the paper an image database system (named SOFIA) with a powerful image retrieval by image features and image content is described. A set of novel image indexing mechanism is proposed. A query by colour, shape, image description and image element description is developed. The SOFIA system is been implemented on IBM PC using Borland C++ under Windows 3.1.

1. INTRODUCTION

With the increase the computer abilities to handle image data the need of image databases increased substantially. There are different research prototypes of image databases, but commercial systems based on image content indexing are still not available.

Traditionally there have been two major approaches to global image representation: ***the parametric*** and ***the syntactic approach***. In the parametric approach image elements are represented by vectors of features (e.g., colour, size, etc.), which features can be measured from the images. In the syntactic representation the image features are represented as sets of symbolic entities, that is an alphabet of image primitives is used. The proposed image indexing mechanism combines the two approaches and allows quick search based on multilevel index. The user can make use besides of simple text-based queries, also of tools for drawing sketches, picking colour from colour palette, drawing image element, extracting parts from example images, etc. The searching mechanism combines image and text description of colour, shape and attribute of the image and its elements. The overall description reduces the search. The image content is defined by tools provided by the todays state-of-the-art computer vision. For defining values of attributes that are beyond the pattern recognition technology, we count on the users themselves.

The work described combines different methods such as: features similarity measure, defined in machine vision [4]; line diagrams and engineer drawings retrieval [9, 12, 13]; preliminary defining of elements and recognition of their position [8, 14]; shape retrieval [6, 7]; methods based on colour retrieval [15]; and image database research prototypes [2].

The main characteristics of the proposed image database system are: (1) possibility to handle large amount of images of different types; (2) possibility for content and similarity based retrieval; (3) possibilities to compose the query of text, images, sketches and making use of colour palette; (4) the query response time is fast.

Possible application areas for the proposed SOFIA image database system could be: geographic maps, medical atlases, architectural plans, medical images, art catalogues, museum catalogues, photo-journalistic images, etc. The SOFIA system will be a part of a future multimedia database system, than will contain text, sound, images and video.

2. THE SOFIA SYSTEM ORGANISATION

The SOFIA system described here incorporates techniques borrowed from image processing, pattern recognition and databasing. The following types of images are allowed in the SOFIA image database system: 2D or 3D images, composed from several 2D image slices. Every 2D slice could be binary - black and white (1 bit), grey scale (1 byte), grey scale (2 bytes), index 256 colour (1 byte) and true colour (3 bytes, a byte for every RGB colour) images. Internal image file format is used in the SOFIA system that contains the image voxels, the *x, y, z*, image dimensions, the number of voxels in *x, y, z* dimension. Converters from the most common image formats are available in the SOFIA system [10]. Various image operations such as voxel operations, neighbourhood operations, morphological operations, etc. [11] are also implemented for reducing the image noise by entering the images into the database system. The architecture of the SOFIA system is shown in Figure 1.

Level	**User**	**Input**	**Processing**	**Result**
Domain definition	Domain experts	Set of elements Set of used features	Image feature processing	Element database Image description database
Image entering	Image entering users	Images	Image indexing	Image database Logical database
Image retrieval	End-users	Query	Query processing	Set of images

Fig. 1. The SOFIA system architecture

Three levels of interaction are provided: domain definition, image entering, and image retrieval. The first level - domain definition is for domain experts, who wish to develop new application areas for the SOFIA system. At the second level images are entered into the system. The third level is image retrieval for the end users who use the SOFIA system only for answering specific queries.

In the SOFIA system images are indexed (e.g., semantic image representation is derived), before storing them into the system. We will discuss in what follows the process of image indexing and than the three levels of the SOFIA system.

2.1. Image Indexing

The basis of image indexing is a semantic image representation. The total image representation is defined as: Global image representation and Image Elements representation, where ***Global image representation = {Image Name, Image Colour, Image Attribute}*** and ***Image Elements representation*** includes the Image element representations and their places. ***Image Element representation = {Element name, Element colour, Element shape, Element attribute}.***

An ***Element*** is a small patch in the image with descriptive power. The best choice for an ensemble element is to form a set from which the image is composed. For geographic maps for instance, the natural set is that of the signs in the legend. For electronic schemes, the sensible set of elements is the set of iconograms of components.

The different elements in the semantic image representations are defined as:

1. ***Name description***. Name of an image or elements in it could be given during the image entering.

2. ***Attribute description***. It is borrowed from outside sources concerning the image elements. In the case of geographic maps, if the element represents a legend sign for a town, the user could enter the town population. The attribute description could be text or number.

3. ***Colour description***. Each image voxel is considered as a point in a 3D colour space (Red, Green, Blue). Colour vector of an image (or element in it) is defined as:

$colour\_vector = (R_{avg}, G_{avg}, B_{avg})$, where,

$R_{avg} = \frac{\sum_{i=1}^{N} R(i)}{N}, G_{avg} = \frac{\sum_{i=1}^{N} G(i)}{N}, B_{avg} = \frac{\sum_{i=1}^{N} B(i)}{N}$, and where N is the number of the voxels in the image or image element, and *R(i), G(i), B(i)* are the red, green and blue component intensities of the i^{-ih} voxel.

In applications such as photo journalism, for a more detailed colour description we define also a 256-colour histogram. We cluster similar colours together using agglomerate clustering technique, and choose one representative colour for each colour “bucket” in the histogram. Each component in the colour histogram is the percentage of the pixels that are most similar to that colour.

4. ***Shape description***. The shape is one of the major characteristics of an image element. The ***shape vector*** is used to present some of the main element shape characteristics. It includes***: area, perimeter, angle of major axis*** [1]. It includes also the first three Fourier coefficients FC_1, FC_2, FC_3, obtained by Discrete Fourier Transform of the function describing the skeleton of the element, obtained with Sobel edge detection filter [11].

Given the semantic representation of images we now get back to the three levels of interactions as displayed in Figure 1.

2.2. Domain Definition

The purpose of the domain definition is to describe the basic characteristics of the application domain of the images in the database system. The domain definition defines the set of characteristics that will be used in the image indexing process. If elements are considered in the applications the corresponding elements are entered. The elements are either entered by a scanner or a camera, or extracted from stored images, or are prepared with the help of some image manipulation functions [11].

2.3. Image Entering

Once the domain of the database has been defined, images can be entered into the database. The image data are stored into the image database. The images are indexed and the image descriptions are stored into the logical database. This process can be done completely automatically or interactively, if this is specified in the domain definition.

Three different techniques are used to segment the image into elements. The use of one or other depends on the application area of the used images and it is specified in the domain definition.

The ***first technique*** is based on search for a specific image element in a preliminary defined element database. The theory of mathematical morphology is used to obtain a correspondence measure between the found instances in the image and the elements in the element database, treated as a structuring element (in terms of mathematical morphology). For this purpose the Hit-or-Miss operation [16] is used. In practice, we prefer to use fuzzy mathematical morphology rather than the exact version. Fuzzy morphology permits for some noise in the image. This method is described in [14].

The ***second technique*** is based on obtaining the image skeleton with the help of the Sobel edge detection filter [11] and square parallelograms containing interconnected lines are treated as elements.

The ***third technique*** is based on recognition of small parts and relations between them. The parts and relations are used to construct Attribute Relation Graph (ARG) [5]. The ARG graph is a relational structure which consists of a set of nodes (lines, arcs, and segments) and a set of branches (join, connect, intersect) representing the relations between the nodes, as both nodes and branches may have some attributes assigned to them. Graph matching techniques is applied to resemble the image elements. The technique is described in [12].

2.4. Image Retrieval

The image retrieval in the SOFIA system allows: (1) "direct query" - the user specifies the query by directly picking colour from the colour palette on the computer screen, and/or drawing an image sketch with the mouse; (2) "image query" - the user asks for images similar to a given image or containing given image; (3) "textual query" - the user specifies a textual description of the search image; (4) combination of all of the above.

Those images which fulfil the query make up the query answer set. In our approach, the query answer is presented by decreasing similarity to the specification, enable the user to evaluate the quality of the matching.

The query language uses: preliminary defined tables and forms where data could be entered, windows for drawing the skeleton or enter example image, colour palette for picking a colour. The formal query language description is given in Appendix 1.

2.4.1. Similarity Calculation

When a query is given a corresponding semantic image representation of the search images is obtain from it. If a colour is picked from the palette, the correspondent colour vector is automatically produced. If an example image is entered, the corresponding indexing is done. If a shape of an element is drawn, the Discrete Fourier Transform of the function describing the element skeleton shape is done, and the obtained first three Fourier coefficients FC_1, FC_2, FC_3 are added to the shape vector.

The similarity measure between two image representations is calculated as weighted difference between the global image representation and element representations. The weights are defined in the domain definition. The names must be identical. The attributes must be identical if they are textual, or in tolerance ε from the given relation. ε is defined in the domain definition. The colour difference is defined as Euclidean difference of the colour vectors. The distance between two colour histograms x_i, and y_i, $(I,j=1,256)$ is calculated as

$\sum_{i=1}^{256}\sum_{j=1}^{256} a_{ij}(x_i - y_i)(x_j - y_j)$, where a_{ij} describe the simultaneity between colour $_I$ and $_j$. The shape difference is defined as Euclidean distance between the shape vectors. Parseval's theorem [3] gives that the obtained first three Fourier coefficients FC_1, FC_2, FC_3 can be used for obtaining the distance between two element shapes.

3. AN EXAMPLE

An example query could be: "Find all 2D colour images with 20% red (no matter what the rest colours are), and in which there is a map of Sofia west of an image element with the following shape ".

The query looks like:

RETRIEVE IMAGES
IMAGE CHARACTERISTICS
DIMENSIONS: 2D
TYPE: COLOUR-1BYTE OR COLOUR-RGB
COLOUR: 20% red
AND
ELEMENTS CHARACTERISTICS
NAME: MATCH map
ATTRIBUTE: MATCH Sofia
POSITION: W
SHAPE: SIMILAR TO SKELETON IN window_1,

where in window _1 with the help of the MS Paintbrush the skeleton of the element is drawn.

4. CONCLUSIONS

In the present paper, the SOFIA image database system with a powerful image retrieval by image features and contents, is proposed. The main advantages of the SOFIA system can be summarised as follows:

- possibilities for storing large amounts of 2D and 3D images, each of large size and different types;
- the image query allows retrieval by image content and colour, shape, image description and image element description;
- fully automatically and/or interactive way of image indexing;
- robustness to noisy recording and inconsistencies in the indexing;
- resemblance measure calculation between the query and the retrieved image;
- simplicity of the query language gives the possibility to learn to compose correct queries in a very short time;

- simplicity of the logical data representation;
- combining image processing function with database functions;
- the index mechanism allows very fast response time.

The SOFIA system is been implemented on IBM PC using Borland C++ under Windows 3.1. The design of the SOFIA system uses an experience gained during the development of the AMSTERDAM image data base system [14], which works with electronic schema images. It uses an image processing and manipulation environment [11].

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Appendix 1.

A formal query description of the used in the image database SOFIA system query language is as follows:

RETRIEVE IMAGES <image clause>, where

<image clause> := *IMAGE CHARACTERISTICS <image description> |*
ELEMENTS CHARACTERISTICS <elements description> |
SIMILAR TO IMAGE <windows name> |
<image clause> AND <image clause>
<window name> := *string*
<image description> := *DIMENSIONS: <dimensions> | TYPE: <type> |*
NAME: <name> | COLOUR: <colour> |
ATTRIBUTE: <attribute> |
<image description> <image description>
<dimensions> := *2D | 3D | 2D OR 3D*
<type> := *BINARY | GREY-1BYTE | GREY-2BYTES |*
COLOUR-1BYTE | COLOUR-RGB | <type> OR <type>
<name> := *MATCH string*
<colour> := *<colour vector> | <% value> % <colours> |*
colour picked from the colour palette |
<colour> AND <colour>
<% value> := *integer in [0,100]*
<colour vector> := *R: <RGB>, G: <RGB>, B: <RGB>*
<RGB> := *integer* $\in$ *[0,255]*
<colours> := *green | red | blue | violet | yellow | pink | light blue | orange*
<attribute> := *<relation> string*
<relation> := *< | > | = | <= | >= | MATCH*
<elements description> := *<element description> |*
<element description> POSITION: <position> <element description> |
<elements description> AND <elements description> |
SIMILAR TO ELEMENT <windows name>
<element description> := *NAME: <name> | COLOUR: <colour> |*
ATTRIBUTE: <attribute> | SHAPE: <shape> |
<element description> <element description>
<position> := *N | W | E | S | SE | SW | NE | NW*
<shape> := *<shape vector> <relation> <value> |*
SIMILAR TO SKELETON IN <windows name>
<shape vector> := *AREA: | PERIMETER: | ANGLE:*
<value> := *float | integer*

where “N”, “W”, “E”, “S” denote the four cardinal points.