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GRAPHICAL IMAGE RETRIEVAL IN MULTIMEDIA DOCUMENT SYSTEMS

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In the paper the problem of retrieving images in multimedia document systems, on the basis of a specification of the image content is discuss. The presented approach allows a limited automatic analysis within the framework of a rule-based system for images from a preliminary described domain. The semantic objects contained in the images are interpreted according to the theory of evidence. The image query processing is based on special access structures generated from the image analysis process.

<u>1. Introduction: The Problem of Image Retrieval. The Image Retrieval in Office Automation. Could DBMS or IRS Techniques be of Help.</u> There is a growing number of application areas where digital image processing is a primary concern. Huge amounts of images in electronic form are produced in environments such as: interactive computer-aided design, geographic data processing, remote sensing of earth resources, regional economic and health data processing, cartographic and mapping applications [10].

When many images have to be computer manipulated, intention to apply the technology of databases naturally appears. In the last decade much of the work in the field of "image databases" appears in the "Proceedings of the IEEE workshops on pictorial data description and management", starting from 1977 and in some other series as: "Computer graphics and image processing", "Computer vision, graphics, and image processing", "Image and vision computing", etc. Several other sources as: the work edited by Chang and Kunii [8], the collections of papers on pictorial applications and information systems - [5], [7], [16] could serve as a good introduction to the field. The valuable survey of Tamura and Yokoya [26] includes insights into many existed approaches, as well as, descriptions of several systems: Graphics-oriented Relational Algebraic Interpreter (GRAIN), Relational Database system for Images (REDI), Database system of Microscopic Cell Images (IDB), etc. and nearly 100 references. Another work [10] besides some software design approaches presents a survey of seven commercial systems, currently available and their software capabilities (Xerox's 8010 Information System, TERA's Automated Records Management Systems, Teknotron's Systems, Scitex's Response - 250, Toshiba's Document Image Filing System DF2100, CCA's Spatial Data Management System, IIS's System 600 series of software products). Different query approaches are described in works as: [11] - for low level image retrieval, [22] - for image retrieval in CAD/CAM systems, [27] - for alphanumerical and picture data retrieval. Picture query languages are described in works as [6], [7]. A review of approaches to machine interpretation of remotely sensed images is presented in [25].

Apart from the fact that systems appearing under the heading "image database" describe often image nondatabase systems or nonimage database systems [19], most of the existed systems are application specific, that is, the manner in which images are stored, organized and retrieved is specific of a certain application and cannot be generalized to different applications. In many systems, images are stored in files which are linked to other image files into structures for image retrieval and presentation according to the logic of the application [18].

Other systems are based on an underlying database whose schema describes the image content and composition [12]. These systems can exploit the flexibility of DBMS. In particular, the query language and the access structures implemented in the DBMS are very powerful for retrieval operations. But they are limited by the fact that the content of the images must be described using data models which are developed for database systems rather than image systems, and so they lack the expressive power needed for images. In fact, images are inherently different from database records: these records can be divided in different classes according to their interpretation. The record structure (i. e. the schema) can be described at class (i. e. type) level. Since the ratio of instances per type is very high for database systems, the resulting storage structures and access methods are very efficient. On the contrary, each image may have its own particular structure, and a whole semantic network [28] may be necessary to completly describe each image instance.

A new application area where the problem of image storing and retrieval has been addressed is office automation. A new information object is defined, the multimedia document, where images are combined with attribute data, text, and voice [29], [15]. Systems for the storage and retrieval of large volumes of these documents are under study [3]. One of the main functions of these systems is the access to multimedia documents based on their content. However, while these systems incorporate efficient access methods for attribute data and text, they can do very little for images. Their approach is often to link images to other more structured components of the multimedia document, and then exploit the combined access to them [29].

For the retrieval of documents by content, multimedia document systems can exploit very efficient techniques borrowed from DBMS [30], when formatted data is concerned, or from Information Retrieval Systems (IRS) [23], when text is concerned. Comparable techniques are not available for images.

The main conceptual problem in dealing with images derives from the difficulty to exactly define and interpret the content of images. Images can be very rich in semantics, but are subject to different interpretations according to the human perceptive or the application domain. On one hand, it is difficult to recognize the objects (with the associated interpretation) contained in an image, on the other hand it is difficult to determine and represent the mutual relationships among these objects, since they form structures which vary greatly from image to image.

For the problem of image retrieval by content, one could think to apply DBMS or IRS techniques. However, with respect to DBMS's, it is difficult to recognize regular structures of objects contained in images, and then organize image instances into a limited number of types, to which the interpretation is associated. This is the approach required by the strictly typed data models adopted in database systems [28]. In IRS, instead, a free formatting of text is allowed, usually respecting some loose hierarchical structuring in sections, sub-sections, paragraphs and sentences. These systems do not attempt to understand the text (unless some expert system approach is adopted), but still allow an effective retrieval on text. In fact, as opposed to image objects, they can exactly recognize words (as ASCII patterns), on which they base their retrieval capabilities, with the possible help of thesaurus to support synonyms [23]. This is possible, in case of text, because a common semantic is associated to the words used in the natural language. Hence, both DBMS and IRS approaches cannot be directly applied to the image retrieval.

2. Our Approach to Image Retrieval. In addressing the problem of image retrieval from volumes of stored images, if we want to think of a system doing for images what DBMS and IRS do for formatted data and text, we must accept some indeterminantness, characteristic of images, and then deal with the inaccuracy introduced by this fact. In [20] an approach based on the fuzzy set theory has been applied to the analysis and description of pictorial images. Certainty factors for the recognition of objects inside the images are computed using fuzzy logic rules.

However, a major practical problem for pictorial images is the element recognition. The first step in the image analysis and recognition process is the decomposition of the images into relevant and identifiable elements, which are the basic components which will constitute the building blocks of the image structure.

In this step, often called segmentation in pictorial image processing [1], the image space is partitioned into meaningful regions, corresponding to image elements. After the segmentation, the system must recognize the tentative elements in the image, matching them with the pictorial representation (eg. icons stored in a catalog) of the elements to be searched (i. e. template elements). In this process, different variations as changes in size, rotation, translation (eg. using discrete Fourier transforms), can be attempted. An additional problem arises when partial element overlapping occurs in the image.

The result of this process should be the set of basic elements recognized and their relative positions. However, this is a highly computing intensive process which often requires special hardware, as array processors, exploiting the inherent parallelism of the algorithms in order to have acceptable response times. In the end, the system might even not be able to exactly identify the single elements.

Instead, in dealing with graphical images we explore the advantage the images not to be entered into the system through a scanning device, but to be generated by some interactive graphical editor. Therefore, the segmentation process is not necessary. Basic elements are recognized without uncertainty since they can be described in terms of the graphics primitives of the graphical editors.

In this paper, an approach is presented for the analysis and retrieval of graphical images. It is required that the images belong to a specific domain which must be described in advance to the system. A limited automatic analysis of the images is performed before storing the images in the database. This process is accomplished using a rule-based system. The interpretation of the content of the images is based on the Dempster-Shafer theory of evidence [17].

The real goal of this image analysis process is not to attempt any deep image understanding, but is to support the image retrieval process. In fact, the system allows the user to query the images, already analyzed and stored, giving some specification of their content. The image query processing is based on special access structures (i. e. image indices) which are generated when the image analysis is performed. The query specification, expressed in a linear query language, indicates the essential features of the images to be retrieved.

3. Main Phases of the Image Retrieval in Multimedia Document System. In the following the domain description phase, the fundamental phases of image analysis, the image storing/indexing, and the image retrieval in multimedia document system are presented in accordance with developed methodology.

3.1. Domain Description. The domain description function supplies with initial information the various phases of image analysis. It comprises: basic elements, relations and correspondent attributes establishment (for basic element organization phase); production rules base development (for recursive object recognition phase); class representative images indication (for image interpretation and clustering phase). All these definitions are presented more explicitely in the descriptions of the correspondent phases.

3.2. Image Analysis. The four phases of image analysis are described in what follows:

3.2.1. Basic Element Organization. In this step the initial representation of the image in terms of a graph of basic elements is generated from the graphics primitives of the whole image.

The graph formalism which we have adopted for this purpose is the Attributed Relational Graph (ARG) [14]. in accordance with wich an ARG is a relational structure which consists of a set of nodes and a set of branches representing the relations between the nodes. Both nodes and branches may have some attributes assigned to them.

If the nodes of an ARG are used to represent the basic elements in the image, and the image properties are assigned as attributes to the respective nodes, and the relations between two basic elements are represented by attributed branches between the corresponding nodes, the following graph of basic elements is obtained: $G = (N, B, A, E, G_N, G_B)$, where N $(N = \{n_1, n_2, \ldots, n_{|N|}\})$ - a finite set of nodes: $|N|$ is the number of nodes in N; B $(B = \{b_1, b_2, \ldots, b_{|B|}\})$ - a set of ordered node pairs (or directed branches), i. e., $b = (n_i, n_j)$ for some $1 \le i, j \le |N|$ denotes the branch emanating from node n_i to node n_j and $|B|$ is the number of branches in B;

A - an alphabet of node attributes:

E - an alphabet of branch attributes;

G_N - a function (or a set of functions) for generating the node attributes:

G_B - a function (or a set of functions) for generating the branch attributes.

For the obtaining of ARG graph structures from graphics primitives a multi-function graphical editor has been developed, which is based on Core graphical standard [24] and incorporates graphical editor functions and ARG techniques. It establishes the graphics elements, relations and correspondent attributes during the application domain description and creates images and generates correspondent ARG representations during the image analysis.

As an attribute of node or branches in an ARG representation the multi-function graphical editor also establishes recognition degree (RD), which represents how close to the exact the node or branch has been found. For the purpose an ARG graph distance measure borowed from [13] is used.

In this phase, since the number of basic graphics elements present inside the image is very large, we have decided not to use a rule system, with a generalized inference mechanism, in order to avoid computational complexity involved in this approach. Instead, for the organization of basic graphic elements into basic image elements of the application, we have adopted the approach based on ARG techniques, which allows the use of object recognition algorithms with polynomial computational complexity. We pay this choice with less flexibility in the description formalism for the basic elements. (In the following phase, for the recognition of more complex and semantically more rich objects, we have used a generalized inferential system, since the number of objects (and rules) in the play is a lot more limited.)

3.2.2. Recursive Object Recognition. The purpose of this phase is to compose more complex objects from the basic elements recognized and organized in the previous phase. This task is accomplished by recursively applying the production rules defined for the particular application domain. We have used an inference mechanism based on backward chaining: the system tryes to recognize in the ARG graph any complex objects, using their recursive definitions.

The rules define also the degree of recognition of an object as average value of RD of all the elements and branches containing this object (determined during the previous step).

After this step a sequence in the form (1) is obtained:

$$\{O_{11}(\mu_{11}, l_{11}), \ldots, O_{1s_1}(\mu_{1s_1}, l_{1s_1})\}, \ldots, \tag{1}$$
$$\{O_{n1}(\mu_{n1}, l_{n1}), \ldots, O_{ns_n}(\mu_{ns_n}, l_{ns_n})\} .$$

Such a sequence describes an image with n distinct physical objects. The unit $O_{ij}(\mu_{ij}, l_{ij})$ is a semantical representation of the physical object i (i=1, 2,..., n) in the image in the j-th (j=1, 2,..., s_j) recognition (i. e. a semantic object). μ_{ij} and l_{ij} are respectively the RD and the list of attributes of the i-th physical object in the j-th recognition.

In our approach we chose the logic programming language Prolog to express the object recognition rules, and a meta-interpretator written in Prolog to perform the object recognition, as part of the image analysis function.

3.2.3. Object Interpretation. Let us suppose that a graph portion, corresponding to a physical object in the image, has been recognized through several rules as different semantic objects each with sertain recognition degree.

New representations of the physical object could be obtained, in which the semantic objects, constructed from identical semantic objects are incorporated, by converting the different recognition degrees into a belief interval. For this purpose the Dempster-Shafer theory of Evidence [17] is applied.

The belief function Bel (O_i) (i=1, 2,..., n) gives the total amount of belief committed to the object O_i after all evidence bearing on O_i has been pooled. The function Bel provides additional information about O_i, namely Bel ($\bar{O}_i$), the extent to which the evidence supports the negation of O_i, i. e. $\bar{O}_i$. The quantity 1-Bel ($\bar{O}_i$) expresses the plausibility of O_i, i. e., the extent to which the evidence allows one to fail to doubt O_i. The interval

[Bel (O_i), 1-Bel ($\bar{O}_i$)]

is called belief interval.

Furthermore, Barnett's scheme [2] is used to compute the belief interval for every object interpretation in the image, as it follows:

First, all recognition degrees of the identical interpretations of a physical object O_i (i=1, 2,..., n) in the image are combined. If $\mu_1, \ldots, \mu_i$ represent different degrees of object recognition, the combined support to the object is

$$p_i = 1-(1-\mu_1)(1-\mu_2)\ldots(1-\mu_i) .$$

Then Bel(O_i) and Bel($\bar{O}_i$) are calculated:

$$Bel(O_i) = K \times [p_i \prod_{j \neq i} d_j]$$

and

$$Bel(\bar{O}_i) = K \times ([\prod_j d_j][\sum_{j \neq i} \frac{p_j}{d_j}]) ,$$

where:

$$K \times K^{-1} = 1$$

and

$$K^{-1} = [\prod_j d_j][1 + \sum_j \frac{p_j}{d_j}] ,$$
$$d_i = 1 - p_i$$

and $j = 1,2,\ldots,n$.

After this step, the sequence (1) is reduced to the sequence:

(2) $$\{O_{11}([Bel(O_{11}), 1-Bel(\bar{O}_{11})], l_{11}), \ldots, O_{1q_1}([Bel(O_{1q_1}), 1-Bel(\bar{O}_{1q_1})], l_{1q_1})\},$$
$$\ldots, \{O_{n1}([Bel(O_{n1}), 1-Bel(\bar{O}_{n1})], l_{n1}), \ldots, O_{nq_n}([Bel(O_{nq_n}), 1-Bel(\bar{O}_{nq_n})], l_{nq_n})\} ,$$

where $q_i \leq s_i (i = 1,2,\ldots,n)$.

In such sequence, objects interpretations with low belief could be omitted.

3.2.4. Image Interpretation and Clustering. The interpretation of an image, as result of the analysis, is in terms of the interpretations of the composing objects. Therefore, the sequence (2) is an image interpretation.

The clustering process consists in adding to the obtained image description information about the membership degree of the image to every defined class. This is made by comparing the image interpretation with all the given class descriptions (i. e. with the class centroid images descriptions). This process is similar to the clustering process in Information Retrieval Systems [23].

The membership degree of an image to a class is assumed to be the inverse of the distance of the image interpretation to the class representative image. The distance between two images is defined as the vectorial distance between their interpretations. According to this, an image is represented by a vector whose elements are the objects, and the value of each element is the mean value of the beleif interval of the corresponding object in the image interpretation. The vector elements should be ordered according to some global ordering of all the objects in the domain: if some object is not present in the image the element value is zero.

After this computation, the clustering description of the image is expressed as a sequence:

(3) $$\mu_1, \mu_2, \ldots, \mu_p ,$$

where μ_i is the membership degree of the image to the class K_i.

3.3. Image Storage and Indexing. We will now discuss the two phases of image storage and image indexing.

3.3.1. Image Storage. In our approach, along with the file containing the image presentation we must also store the added information resulting from image analysis.

The image file will contain the graphical image as the sequence of the graphics primitives used for the image composition by the graphics editor. In our case the image file will be constituted by the SunCore [24] metafile, stored as a set of segments, each containing graphic elements with the associated attributes.

3.3.2. Image Indexing. The complete image description, resulting from the analysis phase, is considered in terms of the probabilistic model as composition of objects, at different level of complexity, with the associted interval of belief. However, it is essential to find a suitable storage representation for this added information since the efficiency of the image retrieval process is based on it. For this purpose, it is useful to define some type of indexing on objects and associated belief intervals.

The image access information is stored in an "image header", associated to the image file. In this header we store:

- One sequence (3), containing the image clustering description. Each term of these sequence contains the membership degree of the complete image in one of the image classes of the application. This kind of information is more synthetical, since it refers to the image as a whole.

- One sequence (2). The same object may appear more times in the sequence, one for each appearance of that object in the image interpretation. This kind of information is more analytical, since it refers to the composition of the image.

Access structures (that is, the image indices) can be built for a fast access to image headers. Two type of indices are constructed:

- Object index. For each object a list is maintained. Each element of the list is constituted by a list of elements (BI, IMH), where IMH is a pointer to an image header, meaning that the object is present in that image, BI is the associated belief interval. For query processing, it is very important to maintain the list in decreasing order of BI. The order is computed using the mean vaues of the belief intervals.

- Cluster index. For each class defined in the application, a list of elements (MD, IMH) is maintained. IMH is a pointer to an image header, corresponding to an image with a non-null degree of membership to this cluster, and MD is the value of the membership degree. For query processing, it is very important to maitain the list in decreasing order of MD.

3.4. Image Retrieval. The query language is an extension to the existed query language [4] developed for text retrieval.

The query statement is in the form: RETRIEVE IMAGES <image_clause>.

The <image_clause> contains the <cluster_clause> and/or the <object_clause>.

The <cluster_clause> is a boolean combination of <cluster_predecate>'s, each of the form: <class_name> <cluster_degree>.

This predicate indicates that the images in the database with a similarity to the named class higher than the <membership_value> should be retrieved (as requested in the boolean expression). The <cluster_clause> may be missing if the <object_clause> is present.

The <object_clause> is a boolean combination of <object_predicate>'s, each of the form: <object_name> <degree_of_recognition>.

The <object_clause> must be evaluated, according to he boolean expression, taking into account only the images in the database containing those objects, named as <object_name>, with the lower value of the belief interval higher than the <degree_of_recognition>. The WITH operator, in a <object_predicate>, serves the purpose of adding conditions to the attributes associated to the object named as <object_name>.

All the stored images having a distance lower than the required accuracy will constitute the query answer set. With this approach, the query answers can be ordered by decreasing similarity to the query specification, so a user may limit the size of the answer and can receive a ranked output of the retrieved images. (These advantages are typical of the information retrieval techniques [23]).

A browsing facility becomes essential in this approach. That is, the user should have the possibility of browsing through the retrieved images. Since the image retrieval is not an exact process (since there is no exact way of defining the image content) and even the user may forget essential characteristics of the sought images, several non pertinent images can be retrieved as a result of a query. Moreover. relevance feed-back and query reformulation [23] are emphasized, since at any moment the user can go back to the query formulation step, if dissatisfied by the results which he is getting, and change some aspects of the query specification.

4. Conclusions. Second prototype is under development. It runs on SUN/3 workstation, under Unix 4. 2. It is written in C and Quintus Prolog and uses the SunCore graphic package.

The first prototype [21] has been implemented on a IBM PC/AT computer and dials with business graphical images, generated by a commercial business graphical editor (i. e. the Graph Assistant). The image analysis process has been implemented using Turbo-Prolog, under MS/DOS.

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ИЗВЛИЧАНЕ НА ГРАФИЧНИ ИЗОБРАЖЕНИЯ В СИСТЕМИ С РАЗНОРОДНО СЪДЪРЖАНИЕ НА ДОКУМЕНТИТЕ

Петър Л. Станчев

В статията се разглежда проблема за извличане на изображения в системи с разнородно съдържание на документите на базата на определяне на съдържанието на тези изображения. Представеният подход позволява частичен анализ в рамките на система правила засягащи изображения от предварително описана предметна област. Семантичните обекти, съдържащи се в изображенията се интерпретират с помощта на вероятности и правдоподобност. Търсенето на изображения се базира на специални структури за достъп, създавани при анализа на изображенията.

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