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AN IMAGE DATABASE MANAGEMENT SYSTEM. FUNCTIONAL DESCRIPTION

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In this paper we address the problem of building a database system for images (IM_DBMS), in which the images can be accessed by a partial description of the image content. The approach allows a limited automatic analysis, using ARG techniques and a fuzzy rule-based system for images belonging to a domain described in advance. The semantic objects, recognized in the images during the analysis process, are interpreted according to the Theory of evidence. The image query processing is based on special access structures generated from the image analysis process. An example demonstrates some of the functions of the IM_DBMS oriented to geographical map processing (input, analysis, storage, retrieval and output).

1. INTRODUCTION

When large amounts of images have to be kept in a computer system, the need to apply database technology naturally arises. In the last decade, much of the work in the field of "image databases" appeared in the proceedings of the "IEEE Workshops on Pictorial Data Description and Management", starting from 1977, and in some other series, such as "Computer Graphics and Image Processing", "Computer Vision, Graphics, and Image Processing", "Image and Vision Computing", etc. Some other essential sources are: the work edited by Chang and Kunii [5] and the collections of papers on pictorial applications and information systems in [3], [4], [9], etc. The valuable survey of Tamura and Yokoya [13] includes insights into many actual approaches, as well as descriptions of several systems, such as the Graphics-oriented Relational Algebraic Interpreter (GRAIN), the Relational Database system for Images (REDI), the Database system of Microscopic Cell Images (IDB), etc. Another work [6] 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.

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 subjected to different interpretations according to the human perception of the application domain. On the one hand, it is difficult to recognize the objects (with the associated interpretation) contained in an image, on the other hand is difficult to determine and represent the mutual relationships among these objects, since they form structures which vary greatly from image to image.

In this paper, a database system for images, IM_DBMS, is presented. It supports the analysis and retrieval of 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 [8]. An example of an implementation of the IM_DBMS for geograhical map system management is also presented.

2. THE IM_DBMS SYSTEM

In IM_DBMS, the images that are input, edited, analysed, stored, retrieved, and output are bit-map images, obtained by an image scanning process, or graphical images, obtained by the means of a graphical editor.

In the system, we can identify six inter-related phases: domain description, image input and editing, image analysis, image storage, image retrieval, and image output and communication.

2.1. Domain Description Phase

The purpose of this phase is to describe the characteristics of the application domain of the images to be stored and retrieved. The domain description operations supply with initial information the various phases of the image creation and analysis. It comprises: establishment of the domain basic elements, for the puproses of the low-level image analysis; description of the possible relations and attributes of the basic elements, for the purposes of object recognition step of the high-level image analysis; indication of representative images, for the purposes of the image clustering step of the high-level image analysis.

2.2. Image Input and Editing Phase

The puprose of this phase is to enter the image into the computer storage. Bit-map images are, normally, acquired by a scanner and are transformed into image binary array form. Graphical images are created by a graphical editor and are transformed in a set of graphical editor primitives.

A set of editing operations has been developed. The operations perform certain transformations on the image to provide a different perspective of it. Another set of editing operations over the image description is also provided. These operations are for changing and updating of the image description information.

2.3. Image Analysis Phase

The process of image analysis is related to the extraction of the image content. It is considered separated into two phases. The first phase, usually called low-level image analysis, includes the extraction of an adequate form of knowledge from the image data and representing it by an appropriate formalism. In the second phase, called high-level image analysis, the actual, in the sense of image meaning comprehension, analysis of the image is performed, using the extracted representation. As a result, a global image representation is obtained.

2.3.1. Low-Level Image Analysis Phase

The low-level image analysis accepts an image (bit-map or graphical) and recognizes the basic elements in it, their relative positions and the associated distinguishing attributes. For this reason we have adopted an approach based on the Attributed Relational Graphs (ARG) [7]. For the attribute calculation a set of operations are available.

2.3.2. High-Level Image Analysis Phase

The high-level image analysis makes use of the information about the elements, contained in the image and their relative position, obtained during the low-level image analysis. It is constituted by the following three steps: object recognition, object interpretation and image clustering.

a) object recognition. The purpose is to recognize semantically meaningful objects from the basic elements, derived and organized in the previous phase. This task is accomplished by recursively applying the production rules, defined for the chosen application domain. An inference mechanism, based on backward chaining, tries to derive from the basic elements

more general objects and to give a recognition degree to the recognized object. In this phase a generalized inference mechanism is used. Its computational complexity is acceptable at this point, since fewer objects (in the order of hundreds) are present in the image.

In IM_DBMS fuzzy rules could also be used. They define the degree of recognition of an object as a distance between objects, implied in the rule and those found in the image.

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

(1)

$$\{O_{1\,1}(\mu_{1\,1}, l_{1\,1}), \ldots, O_{1\,s_1}(\mu_{1\,s_1}, l_{1\,s_1})\}, \ldots, \{O_{n\,1}(\mu_{n\,1}, l_{n\,1}), \ldots, O_{n\,s_n}(\mu_{n\,s_n}, l_{n\,s_n})\}$$

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

b) image interpretation. The image interpretation is constituted by a sequence of all interpretations of the objects found in the image.

Using a procedure similar to Barnett's scheme [1], based on the Dempster-Shafer theory of evidence [8], and fully described in [11], we convert the results obtained from the previous phase into a list of new structures, containing information for each object:

(2)

$$\left\{O_{1\,1}([Bel(O_{1\,1}), 1 - Bel(\overline{O}_{1\,1})], l_{1\,1}), \ldots, O_{1\,q_1}([Bel(O_{1\,q_1}), 1 - Bel(\overline{O}_{1\,q_1})], l_{1\,q_1})\right\}, \ldots,$$

$$\left\{O_{n\,1}([Bel(O_{n\,1}), 1 - Bel(\overline{O}_{n\,1})], l_{n\,1}), \ldots, O_{n\,q_n}([Bel(O_{n\,q_n}), 1 - Bel(\overline{O}_{n\,q_n})], l_{n\,q_n})\right\}$$

Here $q_i \leq s_i (i = 1, 2, \ldots, n)$. The function $Bel(O_{i\,j})$ $(i = 1, 2, \ldots, n,\ j = 1, 2, \ldots, q_i)$ is a belief function [8].

c) image clustering. The clustering process consists in adding to the obtained image a description information about the membership degrees of the image to every defined class. This is made by comparing the image interpretation with all the given class descriptions (i.e. the class centroid images).

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 i-th class.

2.4. Image Storage Phase

The information obtained in the image analysis phase can be used to generate access structures on image content which can be used for efficient image retrieval. The images are stored in a physical image data base (physical IDB) while their descriptions - in a logical image data base (logical IDB).

2.4.1. Physical IDB

The image representation is stored in a file, containing either the graphical image, as a sequence of the graphical primitives, applied for its composition by the graphical editor, or the binary array representation, in a compressed form, in the case of a bit-map image derivation.

2.4.2. Logical IDB

The derived image information, resulting from the analysis phase is stored in the logical IDB. It is expressed in terms of the probabilistic model as composition of objects at different level of complexity, with the associated interval of belief.

The logical IDB containes two tables OBJ_IND and CLU_IND. For each object a row in the table OBJ_IND is maintained, constituted by a: DOC_ID, OBJ_NAME, OBJ_NUM, ATT, VAL, OBJ_CEN, OBJ_CON, OBJ_OVER, BI1, BI2, where: DOC_ID is a pointer to the image identifier; OBJ_NAME is the object name; OBJ_NUM is the number of the object in the image; ATT and VAL are two arrays, with attribute names and attribute values; OBJ_CEN contains the coordinates of the object center; OBJ_CON is an array with the numbers of the contained objects; OBJ_OVER is an array with the numbers of the overlapping objects; BI1 and BI2 are the bounds of the associated belief interval. For each image, rows in the table CLU_IND of elements (DOC_ID, CLU_NAME, DEGREE) are maintained. DOC_ID is a pointer to an image identifier, corresponding to an image with a non-null degree of membership to this cluster. CLU_NAME is the cluster name. DEGREE is the value of the membership degree. Access structures, in the form of image indices, are built for a fast access to logical IDB.

2.5. Image Retrieval Phase

The query language of IM_DBMS is a newly developed language for image retrieval by content.

According to it, the user specifies the image condition in the form: **RETRIEVE IMAGES <image_clause>.**

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

The **<cluster_clause>** is an "OR" combination of **<cluster_predicate>**s, each of the form: **<cluster_name> <cluster_degree>** . By default, the cluster degree value is 1. This predicate indicates that the images in the database with a similarity to the named class higher than the **<cluster_degree>** should be retrieved (as requested in the "OR" expression). The **<cluster_clause>** may be missing, if the **<object_clause>** is present.

The **<object_clause>** is a boolean combination of **<object_group>**s. The **<object_group>** is a group of **<object_predicate>**s and a **<position_relation>**. The **<object_predicate>** has the form: **<object_name> <degree>**. The **<position_relation>**s are E, W, N, S, NW, SW, NE, SE, CONTAINING, OVERLAPPING, where E, W, N, S denote the four cardinal points. The object group is interpreted from left to right. The position relation considers only the two objects which it connects. It is fulfilled if it stands for at least one couple of objects in the image. The WITH operator, in an **<object_predicate>**, serves the purpose of adding conditions to the attributes, associated to the object named as **<object_name>**. The attribute predicate is a boolean combination of attribute names. In the attribute name comparison with a numerical value, by the operation <, <=, >, >=, = and with a string value, by MATCH operation is permissable.

All the stored images fulfilling the query constitute the query answer set. With this approach, the query answers can be ordered by decreasing similarity to the query specification, so an user can receive a ranked output of the retrieved images.

For a chosen image, a set of functions such as: distance, area, min, max, number etc. are avaiable for displaying different characteristics associated with the image.

2.6. Image Output and Communication Phase

After finding the images that satisfy the query specification, corresponding operations for their displaying or printing on a display screen or a hard copy (in different colours, shapes, positions, etc.) can be used. The user can also print out or list the image description information for the obtained images.

The purpose of the communication phase is to organise the image exchange via local area network. The same output can be directed to another node of a local area network.

3. AN EXAMPLE

As an illustration of the IM_DBMS, we briefly discuss the exploitation (phase by phase) of the system for handling geographical maps.

a) Domain Description Phase. For all the basic elements, ARG representations are to be given. The set of basic elements contains: segments, arcs, points and text boxes. At this point, the rules for object recognition are to be defined. Suppose we want to make provision for the recognition of the following objects: states, with attribute "name", cities with attribites "name" and "population", roads with attribute "number", river with attribute "name", etc. Suppose - two images are chosen and entered as class representative images: a political and an iconomical maps.

b) Image Input and Editing Phase. Suppose the map of Czechoslovakia presented in Fig. 1. be among the images stored in the physical image database. It has been input by a scanner device.

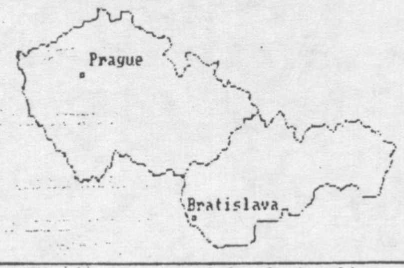

Fig. 1. *A map of Czechoslovakia*

c) Image Analysis Phase. As a result of the image analysis phase, the tables CLU_IND and OBJ_IND are to be obtained.

d) Image Storage Phase. The images, in the compressed form, are stored in the physical IDB. The CLU_IND and OBJ_IND tables, as well as the index files are stored in the logical IDB.

e) Image Retrieval Phase. Suppose maps with the following features have to be retrieved from the image database: to be a political_map (0.8) and to include the cities of Prague and Bratislava. The corresponding query can be expressed, in the following way:

RETRIEVE IMAGES
CLUSTERS *political_map/0.8* AND
OBJECTS *cities/1* WITH *name* MATCH *Prague* AND
cities/1 WITH *name* MATCH *Bratislava*

As a result of the query, a set of images is retrieved from the image database. One of them is the map from Fig.1. Its degree value is 0.92.

Suppose the following queries have to be applied on the map derived (Fig 1.). Display the distance between all cities with population density more than 200 000 people. The corresponding query can be expressed, with:

DISPLAY DISTANCE (OBJECTS *cities* WITH *population* > 200 000)

f) Image Output and Communication Phase. With the help of this phase the obtained images can be displayed or printed.

4. CONCLUSION AND FUTURE WORK

IM_DBMS is under development on SUN/3 workstations, under Unix 4.2. It is being written in C and Quintus Prolog and uses the SUNCORE graphical package.

The design of IM_DBMS is based on the experiences of previuos prototypes. The first prototype, described in [10] and [11], was based on fuzzy set techniques. It was implemented on IBM PC/AT computer and was intended for the management of business graphical images, generated by a commercial business graphical editor (IBM Graph Assistant). Another prototype, working with graphical images, is described in [12] and is applied for house furnishing design drafts.

We plan to apply the results obtained with IM_DBMS in the project MULTOS, which is a part of the ESPRIT (European Strategic PRogramme for Information Technology) and in the project Multimedia information processing, supported by the Bulgarian Academy of Sciences. In MULTOS, a first prototype for the storage (based on optical media) and retrieval of multimedia office documents has already been implemented. However, in this prototype images are treated as passive components in the multimedia documents, that is, components which are retrieved as part of the document but cannot actively contribute in the retrieval process (no condition on images can be part of the query, only conditions on attributes, text and the document structure) [2]. In the second MULTOS prototype, we plan to build a specialized subsystem, functionally similar to IM_DBMS, which will allow a higher integration of images in the document retrieval process.

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