A NEW SOFTWARE TOOL FOR MANAGING AND QUERYING THE PERSONAL MEDICAL DIGITAL IMAGERY

Liana Stanescu, Dumitru Dan Burdescu, Marius Brezovan, Cosmin Stoica Spahiu and Anca Ion
University of Craiova, Faculty of Automation, Computers and Electronics, Craiova, Romania

Keywords: Database management system, content-based visual query, color and texture features, medical image database.

Abstract: The paper presents an original software tool for creating, updating and querying medium sized digital multimedia collections. The software tool represents a relational database management system kernel that uses traditional data types (numbers and character strings) and Image data type to manage visual information. An element of originality is the graphical interface that allows building content-based visual queries using color and texture characteristics. These characteristics are automatically extracted from images when they are inserted in the database. The color information is represented by color histograms resulted by transforming the RGB color space into HSV color space and quantifying it to 166 colors. The texture information is represented by a vector with 12 values resulted from the method that uses Gabor filters. The software tool has the advantage of being platform independent, it has a low cost and it is easy to use by the medical personnel. It is ideal for managing personal multimedia digital collections from medical domain.

1 INTRODUCTION

The private medical consulting rooms represent important components in the medical system. Many of them use medical devices (echograph, endoscope, MRI) to help establishing fast the correct diagnosis. Yearly, they produce thousands of images. That is why the problem of storing the medical image collections in digital format, the associated information (patient name, diagnosis, consulting date and treatment), managing the database and executing efficient queries is intensely studied for finding new and more efficient solutions (Muller et al, 2004, Muller et al, 2005).

A database is created and updated, mainly for using in the query process. One type of query process is the classical one (for example simple text based query). But, for the digital multimedia collection a different type of query should be used: content-based visual query at image level or region level (Del Bimbo, 2001, Faloutsos, 2005, Kalipsiz, 2000, Khoshafian and Baker, 1996). In the first case, the doctor selects a medical image (query image) and searches in the database all the images similar with it and the associated information (diagnosis, treatment). In the second case, the query needs selection of one or several regions in an image and searches in the database all the images that contain selected regions. This type of content-based query is built using visual characteristics (color, texture or color regions) that are automatically extracted from medical images when they are inserted in the database (Del Bimbo, 2001, Smith, 1997). Keywords or other alphanumerical information are not used. This query can be very useful in the diagnosis process or in the medical research process. For example, the doctor can find similar images with the query image or he can see the evolution of the diagnosis for a patient. He can also find similar images with the query image, but with different diagnosis (Muller et al, 2004, Muller et al, 2005).

In order to manage content-based retrieval for medical image collections a series of applications that use traditional database management systems (MS SQL Server, My SQL, Interbase) have been implemented. The complete solution is provided by Oracle - the Oracle 10g database server and Intermedia tool that can manage all kind of multimedia data, including DICOM files. This kind of solution involves high costs for buying the database server and for designing and implementing complex applications for content-based visual query

Stanescu L., Burdescu D., Brezovan M., Stoica Spahiu C. and Ion A. (2009).
A NEW SOFTWARE TOOL FOR MANAGING AND QUERYING THE PERSONAL MEDICAL DIGITAL IMAGERY.
In *Proceedings of the International Conference on Health Informatics*, pages 199-204
DOI: 10.5220/0001538801990204

(Chigrik, 2007, Kratochvil, 2005, Oracle, 2005).

This paper presents a less expensive database management system (DBMS) based on the relational model. The DBMS is platform independent and can easily manage medium sized image collections and alphanumerical information from the medical domain. It has a visual interface for building content based retrieval using color and texture characteristics and can be easily used by any person working in this area, even if he does not have advanced knowledge in using the computer.

Section 2 presents the internal organization of data in the database, sections 3, 4, 5, 6 present the main functions of the DBMS, section 7 introduces some experimental results and section 8 presents the conclusions.

2 DATA ORGANIZATION IN THE DATABASE MANAGEMENT SYSTEM

In this section we describe the information organization in the DBMS.

In the application main folder there is a Database folder, automatically created. This is the place where every new database folder will be created.

Each table in the database is represented by a file with ".tbl" extension stored in corresponding database folder. The file has two components:

- A header – is created in the design phase
- Data area – is updated when executing traditional operations of Insert, Update and Delete

The header structure is made of:

- The number of records in table header (in the header there will be a record for each column in table, a record for primary key, and a record for each external key defined in the table).
- The size of each record from the header (a header record has information about a column of the table: name, type, length – in case of char strings; it can also store information about primary or foreign key/keys).
- The header records.

The DBMS has three types of data: int, char (fixed length strings) and image:

- The information about a char string column type is stored as following:

Table_column_name [blank] char [blank] *no_of_characters*

- The information about a int column type is stored as following:

Table_column_name[blank]int

- The information about a image column type is stored as following :

Table_column_name[blank]image

For the Image data type, in the data area the following attributes are stored:

- Image type (bmp, jpg or gif)
- Image height and width
- Number of bytes needed to store the image
- The image in binary
- 166 integer values, representing the color histogram
- 12 integer values, representing the texture vector.

A series of methods frequently used in the medical domain are also implemented for the Image data type: rotating, zooming, pseudo-colors, the similarity distance between two images, a thumbnail representation, etc.

We describe below the methods used for extracting color and texture information from an image and the reason why they where chosen.

The color space used for representing color information in an image has a great importance in content-based image query, so this direction of research was intensely studied (Del Bimbo, 2001).

There is no color system that it is universally used, because the notion of color can be modeled and interpreted in different ways (Gevers, 2004).

Several color spaces were created for different purposes (Gevers, 2001, Gevers, 2004). The color systems were studied taking into consideration different criteria imposed by content-based visual query (Gevers, 1999). The experiments show that the HSV color system has the following properties (Gevers, 2004): it is close to the human perception of colors; it is intuitive; it is invariant to illumination intensity and camera direction. However, the HSV color space has several problems (Gevers, 2004): nonlinear (but still simple) transformation from RGB to HSV; device dependent; the H component becomes instable when S is close to 0; the H component is dependent of the illumination color.

The studies made on nature and medical images have shown that in the case of the HSV, RGB, l1l2l3 and CieLuv color systems, the HSV color space produces the best results in content-based retrieval (Gevers, 1999, Gevers, 2001, Gevers, 2004, Smith, 1997, Stanescu et al, 2006).

The operation of color system quantization is needed in order to reduce the number of colors used in content-based visual query. The quantization of the HSV color space to 166 colors, solution proposed by J.R. Smith, is the idea used in this multimedia DBMS (Smith, 1997), having as result the color histogram, which is memorized together with the image in the data area of the file.

Together with color, texture is a powerful characteristic of an image, existent in nature and medical images, where a disease can be indicated by changes in the color and texture of a tissue. A series of methods have been studied to extract texture features (Del Bimbo, 2001), but there is not a certain method that can be considered the most appropriate, this depending on the application and the type of images taken into account.

Among the most representative methods of texture detection is the one that uses Gabor filters. This is why it is used in this multimedia DBMS for determining the texture vector.

The color space HSV is a non-linear transformation of the RGB color space. The H, S, V components closely correspond to the human color perceptions.

Starting from the representation of the HSV color space, the color can be represented in complex domain (Palm et al, 2000).

The affix of any point from the cone base can be computed as:

$$z_M = S(\cos H + i \sin H) \quad (1)$$

Therefore, the saturation is interpreted as the magnitude and the hue as the phase of the complex value b; the value channel is not included. The advantages of this representation of complex color are: the simplicity due to the fact that the color is now a scalar and not a vector and the combination between channels is done before filtering.

So, the color can be represented in complex domain (Palm et al, 2000):

$$b(x, y) = S(x, y) \cdot e^{iH(x, y)} \; 4 \quad (2)$$

The computation of the Gabor characteristics for the image represented in the HS-complex space is similar to the one for the monochromatic Gabor characteristics, because the combination of color channels is done before filtering:

$$C_{f,\varphi} = (\sum_{x,y} (FFT^{-1}\{P(u, v) \cdot M_{f,\varphi}(u, v)\}))^2 \quad (3)$$

The Gabor characteristics vector is created using the value $C_{f,\varphi}$ computed for 3 scales and 4 orientations:

$$f = (C_{0,0}, C_{0,1}, \ldots C_{2,3}) \quad (4)$$

This texture vector with 12 values is also stored in the Image type field.

3 DATABASE MANAGEMENT

If the user wants to create a new database, he must provide its name in the dialog menu. If there is another database with the same name, the operation is cancelled and the user is notified. A new folder is created for each database, in the Database folder of the application. After a database was created, it will be listed on the tree in the left side of the main window. This tree is used for viewing all the databases in the system, including their tables. After creating the database, the user might go further to create the tables.

For deleting a database, first it should be selected in the tree on the left side of the window. The user has to confirm operation before deleting. The entire database will be deleted, including the folder and the attached files.

4 TABLE MANAGEMENT

To create a table, the user must select the database where he wants to put it and to specify the name of the table, the columns, primary and external keys if any. The names of the tables in a database are unique. For each table it will be created a new file with a specific structure (a header area and a recording area). This file is created in the database folder having the name of the table and the .tbl extension. The user has to specify the structure of the table: the columns, data type, size, applicable constrains. The name of a column also has to be unique. This aspect is ensured by DBMS.

Three types of data are implemented: int, char and image. For the fixed length char strings the user specifies the maximum size. The database kernel introduces a new type of data – Image. It allows storing in database an image having one of the following formats: bmp, gif or jpg.

When creating a new table, the user may also specify the primary key. It can include one or several columns.

The user may specify a 1:m connection between two tables: a parent table (on the 1 side of the connection) and a son (on the m side of the connection). For this it must be used the Foreign

Keys tag, in the same window. The user can easily select the parent and son table and the foreign key (figure 1). The primary key and the foreign key must have the same type and the same size. If there is a connection between two primary keys, the connection will be 1:1. The structure of the table might be seen at any moment in the main window of the DBMS, using the Components tag.

Once the table is created, we can add new records, modify or delete existing ones, using the record editor.

5 UPDATING TABLE DATA

The user can add a new record only if the previous record was correctly added and saved in the corresponding file of the table. A record is correct if all the fields are filled with information having the type described in the structure. If one of the fields of the table has the type image, when inserting process is started, the "Choose the image" dialog window is opened to permit the user to choose the image he wants to add.

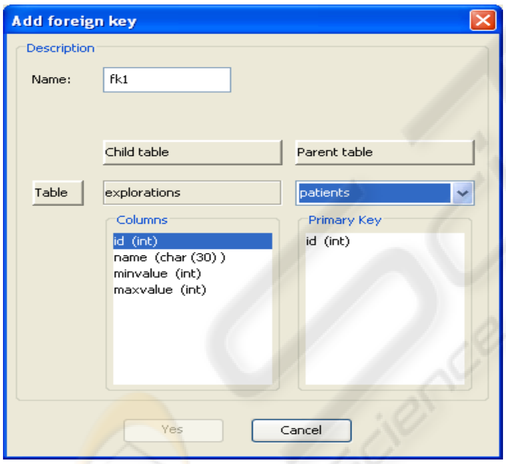

Figure 1: The window for establishing the relationship between tables.

At this moment the algorithms for pre-processing the image will be called:

– Transforming from RGB space to HSV space
– 166 color quantification
– 12 values texture extraction using Gabor filters

The two characteristics vectors and the image are then binary stored.

As we may see, the main window of the application contains two parts: on the left the tree containing the database structure is listed, and on the right is listed the table structure (Components tag) or data information (Data tag). An element of originality is that when seeing the records in the database, the image is directly viewed (figure 2).

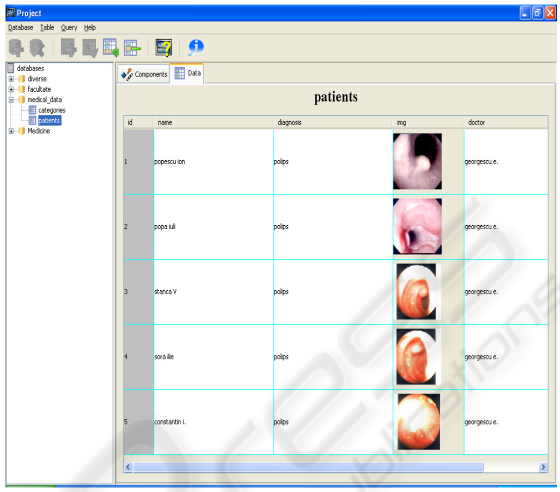

Figure 2: The data in the selected table showed by the Data tag.

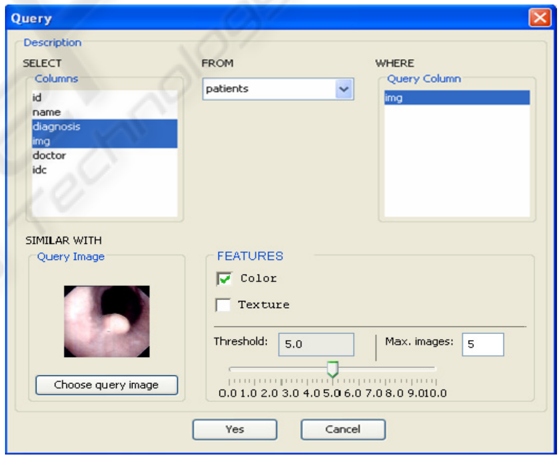

Figure 3: The window that allows the building of the content-based image query.

6 CONTENT-BASED VISUAL QUERY

The database management system kernel offers the possibility to build the content-based visual query, in an easy manner, at the image level, using the menus presented in the software window from figure 3. The elements of this window are:

– Similar With – opens the window for choosing the query image

- Select – permits to choose the field/fields that will be presented in the results of the query
- From – it is one of the tables in database, that will be used for the query
- Where – the image type column used for content-based image query
- Features – it is chosen the characteristic used for content based visual query – color, texture or a combination of them
- Maximum images – specify the maximum number of images returned by the query.

When building the query, it is actually built a modified SQL Select command, adapted for content-based image query. For example:

```
Select patients.diagnosis, patients.img
From Patients where Patients.img
Similar with Query Image (method:
color, max.images 5)
```

This modified Select command specifies that the results are obtained from Patients table, taking into consideration the values from diagnosis field, the images similar with the query image for color characteristic, and there will be 5 resulting images. In the resulting set it is also presented the distance of the dissimilarity between query image and target image. In fact this modified command is very suggestive for the users (medical personnel).

7 EXPERIMENTS

The database management system kernel was tested from two points of view: the quality of the content-based visual query process and the execution speed in a private consulting room specialised in internal medicine. For determination of the query process quality, the experiments were performed in the following conditions. It was created a database with 2036 colour images from the digestive area. The images were taken from patients having the following diagnoses: polyps, ulcer, esophagites, colitis and ulcerous tumour. For each patient there are more images of the same ill area, made from different angles.

For each query, the relevant images have been established. Each of the relevant images has become in its turn a query image, and the final results for a query are an average of these individual results (table 1). These experiments have considered the colour and texture attributes of the medical images, each of them having equal weights (0.5). The motivation of this choice is bound by the nature of medical images from digestive area with different diagnosis that generates changes both in colour and texture of the ill tissue.

Table 1: The content-based visual query experimental results.

Query	Nr. of relevant images	Nr. of relevant images retrieved in the first 5
Polyps	1008	4
Colitis	288	3
Ulcer	540	3
Ulcerous Tumor	80	2
Esophagitis	120	3

In figure 4 there are two examples of content-based image query for images categorized as colitis (first column) and ulcer (the secondary column). In both examples there are 4 relevant images in the first 5 retrieved images in the content-based visual query process.

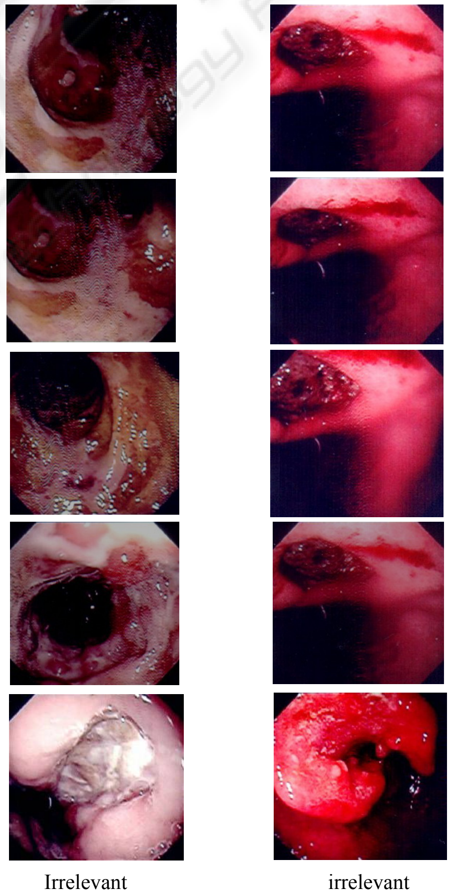

Figure 4: Some results of the content-based visual query process.

8 CONCLUSIONS AND FUTURE WORK

In the paper there are presented the organization and the functions of the implemented multimedia, relational, single-user DBMS kernel. It is created for managing and querying medium sized personal digital collections that contain both alphanumerical information and digital images (for examples the ones used in private medical consulting rooms). The software tool allows creating and deleting databases, creating and deleting tables in databases, updating data in tables and querying. The user can utilize three types of data: int, char and image. There are also implemented the two constraints used in relational model: primary key and referential integrity.

The software tool can execute both simple text based query using one or several criteria connected with logical operators (and, or, not) and content based visual query at image level, taking into consideration the color and texture characteristics. These characteristics are automatically extracted when the images are inserted in the database. The visual manner of building this type of query specific for multimedia data and the modified Select command that is sent for execution to the DBMS give originality to the software product. All the functions of the software tool might be easily used by persons that works in other domains not linked to computers (for example medical domain that use visual information). For implementation the Java technology, which gives the platform more independence was used.

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