IDEA GROUP PUBLISHING
701 E. Chocolate Avenue, Suite 200, Hershey PA 17033, USA
Tel: 717/533-8845; Fax 717/533-8661; URL-http://www.idea-group.com
ITP4733

EMIMS: A Medical Image Management System with a Visual Multi-Criteria Query Interface

David Coquil, Solomon Atnafu, Lionel Brunie
LISI - Institut National des Sciences Appliquées
20 Avenue Albert EinsteinF-69621 Villeurbanne - France
e-mail: {dcoquil, satnafu, lionel.brunie}@lisi.insa-lyon.fr

Richard Chbeir
LE2I - Université de Bourgogne
21078 Dijon CEDEX
richard.chbeir@ieee.org

ABSTRACT
There are two major challenges in image data management: the integration of low and high-level features of images for retrieval purpose, and the adoption of these features with the classical DBMS to satisfy different types of applications. In our previous work, we addressed these challenges for a medical application by proposing a new image data repository model and introducing a novel system of similarity-based operators [11, 13]. In this paper, we present a prototype called Extended Medical Image Management System (EMIMS) implementing our previous proposals. EMIMS is designed to merge several facets of medical image management requirements with a generic repository model to offer new content-based [1] operators that allow users to express multi-criteria queries. We first present the architecture of EMIMS and then demonstrate its different components. We also show how a user is able to express a combination of relational and content-based queries using its visual interfaces.

1. INTRODUCTION
During the last two decades, a lot of work has been done in order to integrate image data in the standard data processing environments [3, 4, 6]. In this respect, two different approaches of image retrieval were proposed: the metadata-based and the content-based approaches. The metadata-based representation uses alphanumeric attributes to describe the context and/or the content of an image. Hence, metadata are stored as accessory information to the visual objects. Retrieval by metadata representation follows the traditional techniques of DBMS [8, 10]. However, it is often difficult or even not possible to fully or adequately describe an image using metadata representation. The second approach for retrieval of images that is practiced since the beginning of the 1990's uses low-level features of images such as their color, texture, and shape [1, 2]. Though image retrieval using these features is done by methods of similarity and hence is a non-exact matching, the research efforts exerted on it have made this approach promising [2, 4, 6, 7]. This method has been adopted in different application areas such as in medicine, security, Geographic Information Systems, etc. In the medical domain, content-based image retrieval is used to assist training, enhanced image interpretation, clinical decision-making, automated archiving, etc. However promising this content-based approach can be, the importance of using metadata cannot be ignored, as there are useful information that cannot be directly extracted from the content of an image. For example, in the medical domain the previous medical history of a patient is relevant information that can only be properly described using metadata textual representation. The current trend is then, towards systems that use a combination of both these metadata- and content-based approaches.

To support content-based image retrieval in the standard DBMS, a number of initiatives exist both in the research and commercial environments (QBIC in DB2 [3], the interMedia Engine of Oracle [7], the Excalibur Image DataBlade module in Informix [5], DISIMA [9]). However, none of the above does support all the necessary operations one needs for an effective image database management. For instance, they are limited in supporting mixed queries involving both content-based and relational operations such as:

Query 1: Retrieve all brain X-rays taken between 01/01/2000 and 12/31/2000 where an anomaly is positioned as the image on the screen (upper-left part of the left lobe), identified as hypervascularized tumor, with a dark gray dominant color, and a volume greater than 30 mm^3.

Furthermore, operations such as the "*similarity-based join*[2] " are not supported by these systems. The commonly practiced feature of these systems is that, given a query image, they search its most similar ones from a list of images using their respective content-based image retrieval engines. That is, the attempts so far did not exceed from these one-to-many content-based image retrieval operations. For instance, let us take a query (Query 2) that requires an image-oriented join operation (i.e. a join on the low-level image representation components of image tables). Consider the two object-oriented schemas of medical image database tables: Patient(Name, Age, Address, Image) and Pathology(Image, Anomaly, Treatments), where the Patient table contains personal data of patients without any metadata description of the images and the Pathology table contains images and their fully annotated thesaurus of all anomaly cases. If physicians or researchers need to get more information on patients having similar anomalies that exist in the Pathology table, they need to make a similarity-based join on the image content descriptions:

Query 2: *Retrieve all personal data of patients having similar anomalies of lung X-rays with its corresponding treatments in the Thesaurus image table.*

The challenge of integrating such type of query processing with the current practices of database management systems is a hot research issue in multimedia data management. For efficient image retrieval, a convenient image data repository model is crucial. The better the features of the image data are represented, the more the image retrieval is able to satisfy complex queries. In this respect, we presented a novel data repository model in a previous paper [11]. This repository model can effectively facilitate multi-criteria queries. Our data repository model permits to track similarity-based associations of two or more image tables and enables to perform a combination of relational and similarity-based operations. In this paper, we present a new version of our prototype MIMS, called Extended Medical Image Management System (EMIMS). Our prototype effectively considers multi-criteria image retrieval and integrates visual user interfaces that permit to visualize images built on top of the existing facilities of traditional DBMS. Though our prototype is developed for medical applications, the principles can be extended to other application domains as well.

The rest of this paper is organized as follows. The architecture of EMIMS, its structure, and its visual interfaces are presented in Section 2. Conclusions are given in Section 3.

2. EMIMS: EXTENDED MEDICAL IMAGE MANAGEMENT SYSTEM

Based on an extension of the description model of our prototype MIMS [12], EMIMS provides very ergonomic interfaces able to store and retrieve medical images using low and high-level features. Thanks to its architecture and repository model, EMIMS allows to formulate multi-criteria queries including similarity-based joins between two or more image tables. Below, we first present the general architecture of EMIMS and then, we describe the structure of the prototype and its different interfaces.

2.1 General Architecture

Considering the requirements for an efficient image data management, we present here a simplified general architecture for an image DBMS in an Object-Relational paradigm. We show that similarity-based operators can work in association with the existing image management systems. To realize this, we define our architecture as an extension of the traditional ORDBMS. The architecture is composed of several components as shown in Figure 1. A Standard Query Processor (SQP) component exists in any of the current DBMS. It consists of all the components such as parser, rewriter, algebraic protocols, and query optimizer. The SQP interacts with the Image Query Processor (IQP) that provides certain routines used in many DBMSs to enhance its image management capabilities. The IQP extends the query system with the similarity-based operators that we proposed in [11]. Currently, it manages the similarity-based operations and the image processing engines. The Data

Figure 1: An architecture for an image DBMS with Multi-Criteria Query.

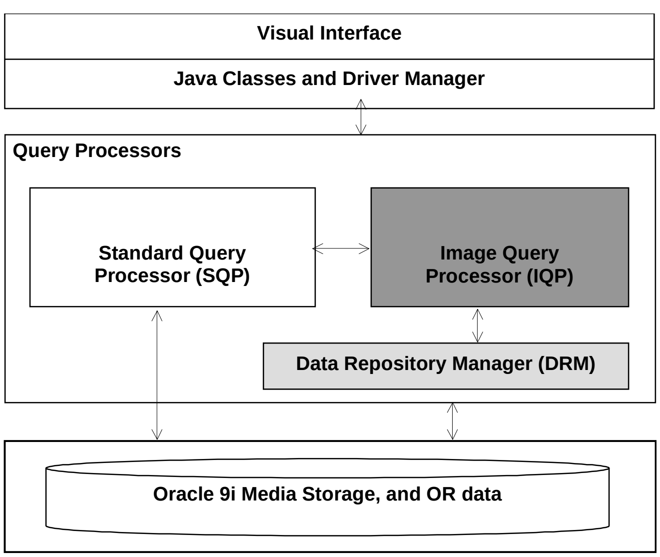
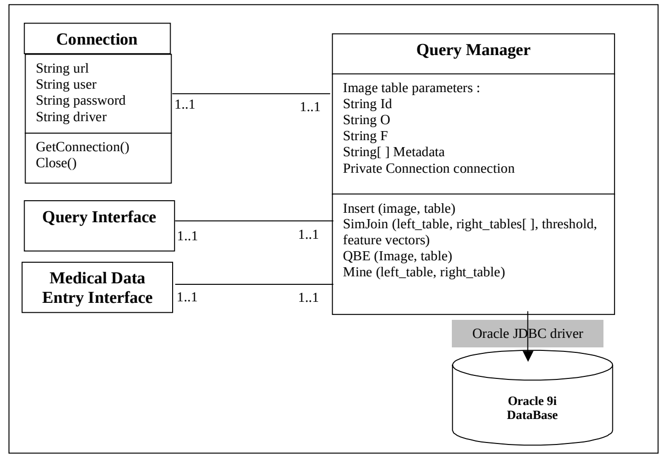


Figure 2: EMIMS Classes Diagram.



Repository Manager (DRM) is the component that is responsible for storing the image related data in an ORDBMS. The DRM also tracks the association between the image tables based on the similarity-based operators.

2.2 The Structure of EMIMS

In order to obtain a platform and database-independent application, we chose to implement EMIMS in Java programming language. EMIMS is designed as either an applet that can be accessed on the web or as a standalone application. Through Oracle's JDBC Driver Manager, EMIMS interacts with an Oracle 9i database. Figure 2 shows the class diagram of EMIMS in UML representation.

Below is a brief description of each of the classes:

- **Medical Data Entry Interface:** is also a Swing JApplet designed to enter the different types of medical data (see section 2.5.1 for more details).
- **Query Interface:** is a Swing JApplet interface designed to formulate queries (see section 2.5.2 for more details).
- **Connection**: is a class that creates a connection to the Oracle 9i database server and maintains it until the user quits the program. It uses the URL of the database server, the username, the password, and the database driver path as attributes.
- **Query Manager**: performs all of the query operations including the similarity-based operations through the Oracle's JDBC Driver. With respect to our repository model, the Query Manager uses the structure M(Id, O, F, A, P) for all image tables where:

  - **Id**: is a unique identifier of the image record in the image table. It is the primary key of the image table.
  - **O**: is used to store the raw image data in the form of OrdImage data type of Oracle 9i. OrdImage is an extension of a BLOB data type.
  - **F**: is the feature vector representation of the image. It uses the OrdImageSignature data type of Oracle 9i. It includes the descriptions of the image in terms of color, shape, texture, and location features.
  - **A**: contains an alphanumeric metadata structure that contains a semantic data related to the image or a key that associates the image with other tables.
  - **P**: is a table of vectors that keeps track of the association between image tables with a similarity-based operation. It is composed of three components:

- Id: is the identifier of the record whose image is found to be similar.
- Table: is the name of the associated image table by the similarity-based operation.
- Score: is the similarity distance rate between two compared images. Score is a real number between 0 and 100. A zero score means that the two images have the highest similarity.

These classes implement different components of the architecture presented in Figure 1. The Query Manager class implements a part of the Image Query Processor. The Medical Data Entry Interface and the Query Interface make the Visual Interface presented in the architecture. The Connection class implements the Driver Manager component of the architecture.

When EMIMS is launched, an instance of the Query Manager class is created. Then, the new object establishes the connection with the database server by creating a Connection object. During this session, each user action that requires an access to the database is translated to the DBMS using the methods of the Query Manager object.

2.3 The Methods of the Query Manager

The main methods of the Query Manager class are:

- **SimJoin:** performs a similarity-based join operation between a reference image table and one or more other image tables. This operation creates a new table with identical schematic structure. This table contains all the records of the reference image table whose image components are found to be similar with image components of the other tables.
- **Query by Example (QBE):** for a given example image, it searches all similar images in a specified image table. A result of this query is an image table with all pertinent records of the specified table.
- **Insert:** transfers an image from the operating system into an image table chosen by the user. It converts the image to an OrdImage data type, generates its signature, and updates its F component.
- **Mine:** from a given result table of a join, M_1ÄM_2, Mine extracts the join M_2ÄM_1 using the contents of P of M_1ÄM_2. It is important here to recall that the similarity-based join M_1ÄM_2 is not symmetric and hence the two are different tables. The mine operator can best be exploited for the purpose of query optimization. That is, based on the cost of computing M_1ÄM_2 and M_2ÄM_1, it is possible to compute the one with the least cost and then apply the mine operator, if it pays to do so.

For all similarity-based operations, there are two parameters to specify:

- *Threshold*: is a normalized rate of similarity that is chosen by the user for the similarity-based operation. It specifies the maximum similarity score between two images signatures to be selected as similar. Its value ranges between 0 and 100.
- *Feature coefficients*: specifies the weight to each visual feature attribute (Color, Texture, Shape, and Location) to be used for the similarity-based comparison. The value of each coefficient is a real number that varies between 0 and 1.

An image similarity engine that is integrated in the database system as a plug-in performs the comparison between two images for similarity. This engine returns the similarity score (a value in an interval [0,100]) as a result of the comparison of the respective feature coefficients representing the image. If this score is lower than the specified threshold, the two images are considered similar.

2.4 Structure of the sample database used in EMIMS

For the purpose of demonstration, we have created a small size medical database. Tables in this database are:

- *Doctor*(**DSN**, FirstName, LastName, Specialization, P_history); for information related to a medical doctor that is uniquely identified by the Doctor's Security Number (DSN).
- *Hospital*(**H_Code**, Name, Address, Sections); for information related to a hospital that is uniquely identified by the Hospital Code(H_Code).
- *Medical_Exam*(SSN, DSN, H_Code, **ME_Code**, DateOfExam, Clinical_P, Case, M_History, Findings, Diagnosis, M_Image); for a detailed medical exam record identified by the primary key Medical Exam Code (ME_Code).
- *Image_Description*(ME_Code, DSN, I_Specified, DeviceUsed, I_Analysis); for a textual description of the image and the device used.
- *Patient*(**SSN**, FirstName, LastName, DateOfBirth, R_Address, R_History, M_History); identified by the Social Security Number (SSN) field

All image tables in the database have the following structure:

- M_i (ID, O, F, ME_Code, Image_Path, P), where i is an index of the form 1, 2, 3, …

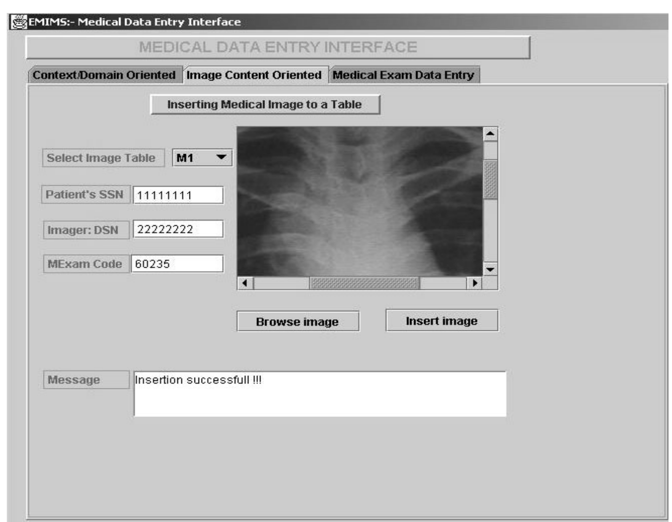
The ME_Code field allows to retrieve information related to an image in M_i from the other relational tables. We have filled the M_i tables with a collection of lung x-rays available on the Web[3].

2.5. User Interfaces

Here, we present the two interfaces of EMIMS: the data entry interface and the query interface. The data entry Interface is composed of three panels:

- **Context/Domain-Oriented Data Entry Panel**: is an interface to enter the data related to the patient, the medical doctor, and the hospital.
- **Image-Oriented Data Entry Panel** (Figure 3): is a panel used to select an image from the operating system. The "Browse Image" button allows selecting the local image stored externally for insertion in the image table. The "Insert Image" button transfers the selected image into a specified image table. Furthermore, this button automatically calls the image processing method that generates the signature of the image to update the F field of the image table. This panel also identifies the SSN of the patient and the DSN of the doctor who took and analyzed the image.
- **Medical Exam Data Entry Panel**: is a panel used to enter the medical exam data related to the patient and all the analysis and diagnosis associated to the medical image.

Figure 3: Image-Oriented Panel in the Data Entry Interface.



2.5.2 The Query Interface

The Query Interface contains three panels:

- **The Relational Query Panel**: is a panel used to formulate queries using icons. This panel is migrated from our previous version of the prototype MIMS, and will not be detailed here. We invite the reader to see our previous publications [12] for more details.
- **The Query by Example Panel**: is a panel for a Query by Example (QbE) similarity-based selection operation (Figure 4). Unlike other systems, our QbE has many additional interesting features:

  - It produces an image table that contains all the image records selected by the operation. The creation of this table makes this selection operation satisfy a closure property like other relational operations.
  - It displays the result table, where the P column is viewed as a combo box component that contains the name of the searched table and the similarity score of the image found.
  - It also displays all the images of the result table with associated metadata and two buttons that allow to retrieve further information on the image by performing a relational selection on the Patient and Medical_Exam tables of the database.
  - In addition to displaying the results, it also displays the associated SQL command. This command can be modified for re-execution.
  - Furthermore, the result table can be saved in the database for future operations.

- **The Multi-Criteria Query Panel**: is a panel that is used to perform operations such as similarity-based join, multi similarity-based join, mine, etc. (Figure 5).

For a similarity-based join operation, we first choose the reference image table, and then we select the image table(s) with which the join will be performed. As a result of this join, an image table is created. This image table contains the image records of the reference image table for which similar image(s) were found in the right table(s). The "P" column of this table is displayed as a combo box. Clicking on the combo box shows a list of vectors (table name, identifier, and similarity score). Each vector on the list corresponds to one similar image in the similarity-based operation. The components of the vector are:

Figure 4: The QBE Interface of EMIMS

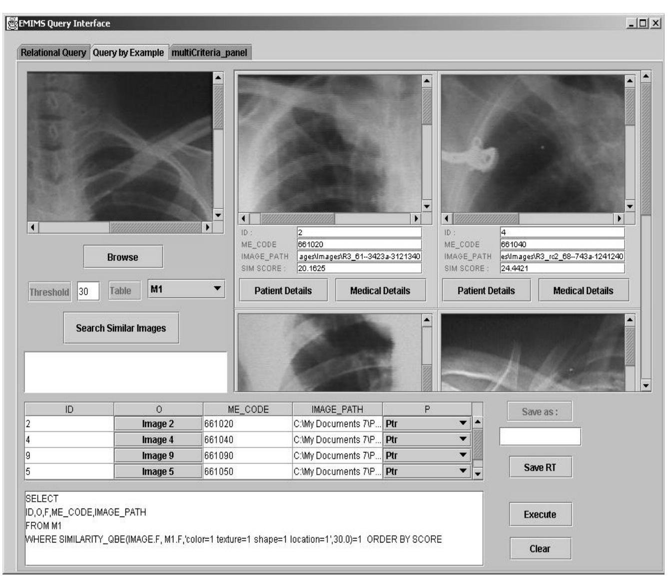
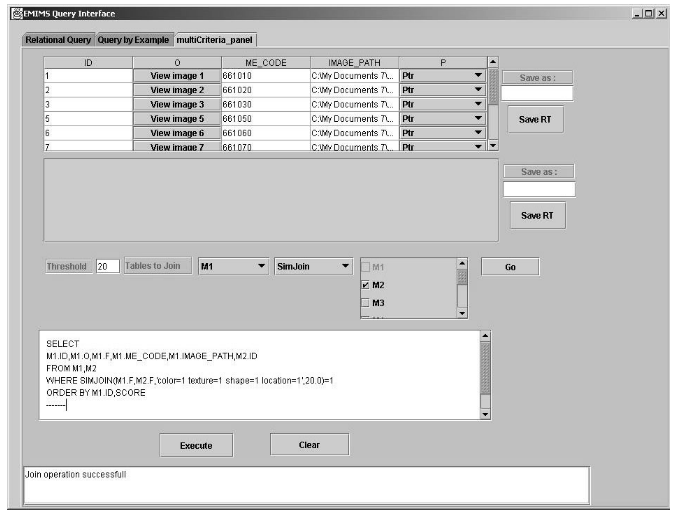


Figure 5: The multi-criteria query panel interface of EMIMS



- Table name, which is the name of the right join table,
- Identifier, that identifies the image record in the right join table, and
- Score, that is the similarity score between two compared images. It is determined by image similarity engine that is integrated in the database system as a plug-in.

The "O" column of the result table is displayed as a button. A click on this button opens a popup window that displays the selected image in the reference table and all its similar images in the right join table(s). As in the QbE panel, each displayed image is associated with two buttons that allow retrieving further information on the image.

Once a similarity-based join, say M_1ÄM_2, is performed, the mine operator can be applied to extract the converse of the join, M_2ÄM_1. The result table of the mine operation is extracted from the P component of M_1ÄM_2. The reason of applying the mine operator is discussed above. The result table of mine is displayed in a panel below the result table of its corresponding join.

The displayed result tables can be saved and be made part of the database system for further operations. Furthermore, for each similarity-based join, the corresponding SQL query statement is displayed in a separate panel. This SQL statement can be edited and re-executed for another query.

3. CONCLUSION

The need for an efficient image management system is becoming an important issue in many application areas such as medical domain. Based on the image data model and the similarity-based algebra presented in our previous publications [11, 12, 13], in this paper, we proposed a prototype for a medical image management system called EMIMS. We first defined the architecture for this system that integrates the relational operations with content-based image retrieval, which consider the low-level features of images. With EMIMS, we developed a visual multi-criteria query interface that enables to formulate both or a combination of the traditional query operations and the similarity-based operations. EMIMS has in practice demonstrated the functionality of the novel similarity-based operations presented in [11].

Future work in this domain includes: the integration of similarity-based operations on salient objects in EMIMS and the extension of this method to other image application domains.

ENDNOTES

1 In this paper, we use the terms content-based and similarity-based interchangeably.

2 A similarity-based join is a join between two image tables using the image representation component as a join attribute. Formal definition is given in a previous article [11].

3 http://www.radiology.co.uk/xrayfile/xray/cases/4/skel.htm.

REFERENCES

[1] Wu, J.K., Narasimhalu, A.D., Mehtre, B.M., Lam, C.P., and Gao, Y.J. (1995). CORE: A content-based retrieval engine for multimedia information systems, **Multimedia Systems**, 3, pp. 25-41.

[2] Berchtold, S., Boehm, C., Braunmueller, B., Keim, D.A., and Kriegel, H.P. (1997). Fast parallel similarity search in multimedia databases, **SIGMOD Conference**, AZ, USA, pp. 1-12.

[3] Yoshitaka, A. and Ichikawa, T. (1999). A survey on content-based retrieval for multimedia databases, **IEEE Transactions on Knowledge and Data Engineering, 11**(1), pp.81-93.

[4] Rui, Y., Huang, T.S., and Chang, S.F. (1999). Image retrieval: Past, present, and future, **Journal of Visual Communication and Image Representation,** 10, pp.1-23.

[5] **Excalibur Image Datablade Module User's Guide,** (1999). Informix Press, March, Ver. 1.2, P. No. 000-5356.

[6] Grosky, W.I. (1997). Managing multimedia information in database systems, **Communications of the ACM, 40**(12), pp. 72-80.

[7] Eakins, J.P. and Graham, M.E. (1999). Content-Based Image Retrieval: A Report to the JISC Technology Applications Program, January, Inst. for Image Data Research, University of Northumbria at Newcastle.

[8] Sheth, A. and Klas, W. (1998). **Multimedia Data Management: Using Metadata to Integrate and Apply Digital Media,** McGraw-Hill, San Francisco.

[9] Oria, V., Özsu, M.T., Iglinski, P., Lin, S., and Yao, B. (May, 2000). DISMA: A distributed and interoperable image database system, SIGMOD 2000, **In Proceedings of ACM SIGMOD International Conference on Management of Data,** Dallas, Texas.

[10] Duncan, J.S. and Ayache, N. (January 2000). Medical image analysis: Progress over two decades and the challenges ahead, **IEEE Transactions on Pattern Analysis and Machine Intelligence, 22**(1).

[11] Atnafu, S., Brunie, L., and Kosch, H. (July, 2001). Similarity-based operators in image database systems, **WAIM'2001,** LNCS, Xi'an, China, pp. 14-25.

[12] Chbeir, R., Amghar, Y., and Flory, A. (2001). A prototype for medical image retrieval, **International Journal of Methods of Information in Medicine**, Schattauer, Issue 3.

[13] Atnafu, S., Chbeir, R., and Brunie, L. (July 2002). Efficient content-based and metadata retrieval in image database, **Journal of Universal Computer Science, 8**(6) (http://www.jucs.org), Springer Co. Pub.