DESIGNING A PICTORIAL DATABASE SYSTEM FOR MEDICAL APPLICATIONS

Mohamed A.Ismail, Mohamed S.Selim, and Amani A.Saad
Department of Computer Science and Automatic Control
Alexandria University, Alexandria, Egypt.

ABSTRACT

The design and implementation of a general medical pictorial database system are presented. The system is to be used by a doctor in a clinic, a hospital or an image analyst whose aim is to develop feature extraction routines for automatic and semi-automatic diagnosis. A set of operations is provided which includes image input/output, image processing, statistical analysis, library maintenance and user-defined operations. A user-friendly interface allows the doctor to: (i) manage his patient images as well as alphanumeric data, (ii) extract useful information from them by specially designed processing packages utilizing the system basic operations, and (iii) keep track of a reference image library which he can build for comparison purposes.

I-INTRODUCTION

Image database systems have applications to a wide variety of fields. A number of medical fields such as ophthalmology, radiology, nuclear medicine, dermatology, pathology and plastic surgery utilize images for key portions of their work. In addition, image database systems can aid in medical education activities. For research laboratories, it is often important to store images as well as numbers and text, and to retrieve them for later comparisons. Image database systems can now make both text and images available to the physician, providing opportunities for utilizing information that were not previously possible [1].

Compared with other kinds of applications, the medical images are diversified. During the early 80s many systems for special kinds of medical images were built [2-6].These systems were at their experimental stages but to use them in clinical medicine the cost/performance ratio and the user interface had to be much more improved [7].

Nowadays, medical information systems are among the fastest growing application areas which integrate local area networks, advanced workstations, and advanced image processors to provide an integrated environment serving a hospital or health care delivery institution. The concept of medical archiving and communication systems (MACS) requires the design of sophisticated pictorial information systems with flexible user interfaces [8].

The system presented is aimed to be a general medical image database system. It can be used in a doctor's clinic, a hospital or a medical research center. The requirements of flexible manipulation and user friendliness are satisfied by an easy to use interface. The operations provided consider the requirements of a doctor in his clinic and an image analyst in a research center whose aim is to develop image analysis and feature extraction routines for automatic and semi-automatic diagnosis. The system considers building a library of typical cases which is to be used as a reference for comparison purposes.

- Section II presents the system design pointing out the major design considerations and introducing the system organization.
- Section III discusses the data representation issues presenting the different data and file types used in the system and introducing the logical data model.
- Section IV lists the different categories of operations provided by the system.
- Section V explains how the system interface is used to formulate a query.
- Section VI discusses the system

implementation.
- Section VII presents a case study.
- Finally, Section VIII concludes this work.

II- SYSTEM DESIGN

Pictorial DataBase Management Systems (PDBMS) differ greatly in their models, data structures, major functions and architectures due to different design considerations. The factors that were taken into consideration in this design are presented in subsection A while the system organization follows in subsection B.

A- Design Considerations:

1) Application area and the kind of images dealt with. The system considers medical information systems and variant medical images such as fluorescein angiography images.
2) The level of abstraction needed. The images are stored as well as symbolic information about them.
3) What is the unit of an image entity ? The whole image or a user-defined window taken from it are considered.
4) What is the level of retrieval ? The expected output might be an image or some relevant information.
5) When are image features computed ? Image features are extracted and entered by means of the user in advance or the system capabilities can be utilized to extract them at retrieval time. General feature extraction routines can not be implemented in advance due to the nature of medical images but specific routines can be augmented to the system as user-defined operations whenever needed.

B- System organization:

The system is designed as an extension of a relational database system by providing an interface that deals with pictorial data. The interface invokes specially designed operations that perform image input/output, image processing, image manipulation, statistical operations, and provide facilities for user-defined programs to be augmented whenever needed.

The system operations can access both kinds of data; pictorial data stored in an image store and alphanumeric data in the form of relational tables and text files. Figure (1) shows a layout of the system organization.

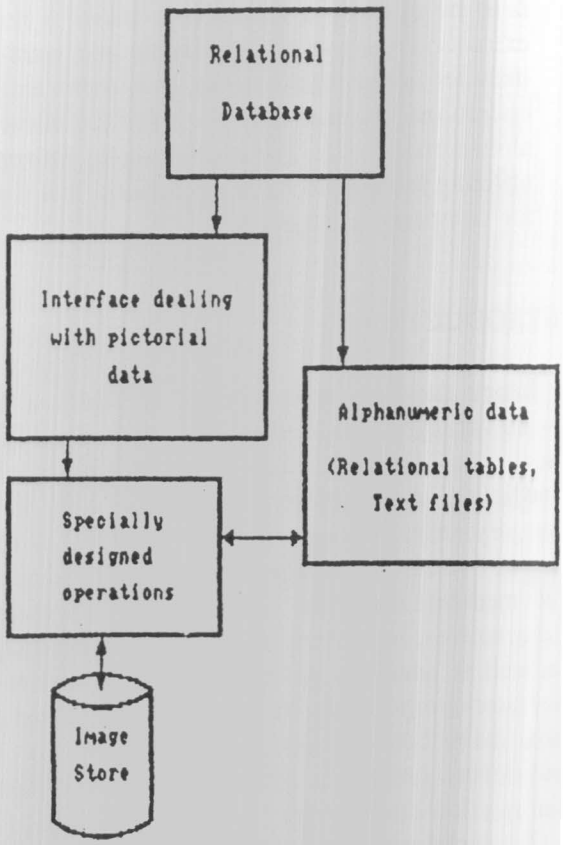

Figure 1. System organization.

III- DATA REPRESENTATION

In this Section, the different data types used in the system are presented and the logical data model is discussed.

A- Image data:

An image is represented in the grid format as a two dimensional array of pixels. The grid format is suitable for the medical images which

have gradual transitions between gray levels and usually do not have well defined features that can be represented by the topological format. The resolution of the digitizer used is 480 rows by 520 columns. Image compression is performed by means of the differential shift encoding algorithm [9].

B- Image descriptors:

The different image descriptors used in the system are:

i) The unique image identifier:

A unique image identifier UID is given for every raw image in the system. A unique product UPID is given for every image generated in the system as a combination of the raw image number and a version number.

ii) Secondary information:

A variety of application dependent information can be stored with every original version of an image as image associated data [10].

iii) Image processing history:

An original image may be processed once or several times in the system. For every processed image, the series of operations performed on the raw image to produce it and the parameters used are stored in an original image history file.

C- File types:

Files used in the system are classified into logical and physical files. The logical files are the relational tables which are used to represent the logical design of the database. The physical files are of two types; image files and text files. Image files are computer compatible files resulting from image digitization. They consist of the image size information as a file header followed by the array of pixels representing the image. While text files are usually comment files that are used to store the analysis of the doctor to a certain image, descriptive information about its features or any other comments. Figure (2) shows the different file types in the system.

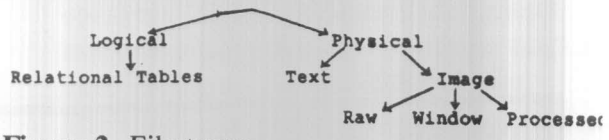

Figure 2. File types.

D- The logical data model:

The major entities involved in the data model of the presented system are stated as follows:

a) The patient .
b) A patient image.
c) A library image.
d) An Image feature .

Two sets of images exist in the system proposed; those belonging to patients which the doctor has to input, manipulate or output regularly, and those stored in the system as typical cases for diagnostic purposes and are gathered in a separate library. The doctor can use existing library images for the sake of comparison and can also update his library contents whenever needed. Every raw image in the system whether a patient's image or a library image may be processed by the different operations in the system once or several times. The processed versions of every image and the corresponding operations with their parameters are considered in the model. Also, features of an image may be extracted by the user or by feature extraction operations and are stored as image related information.

The relations representing the data model are presented in Figure (3).

The following remarks should be stated about the above relations:

- The image file name and version file name are names of files used to store images in physical storage. They are considered as pointers to images.
- Oper1, oper2 and oper3 are abbreviations for first operation, second operation and third operation performed on the raw image to produce this version. Similarly, par1,par2 and par3 are the parameters used in these operations.

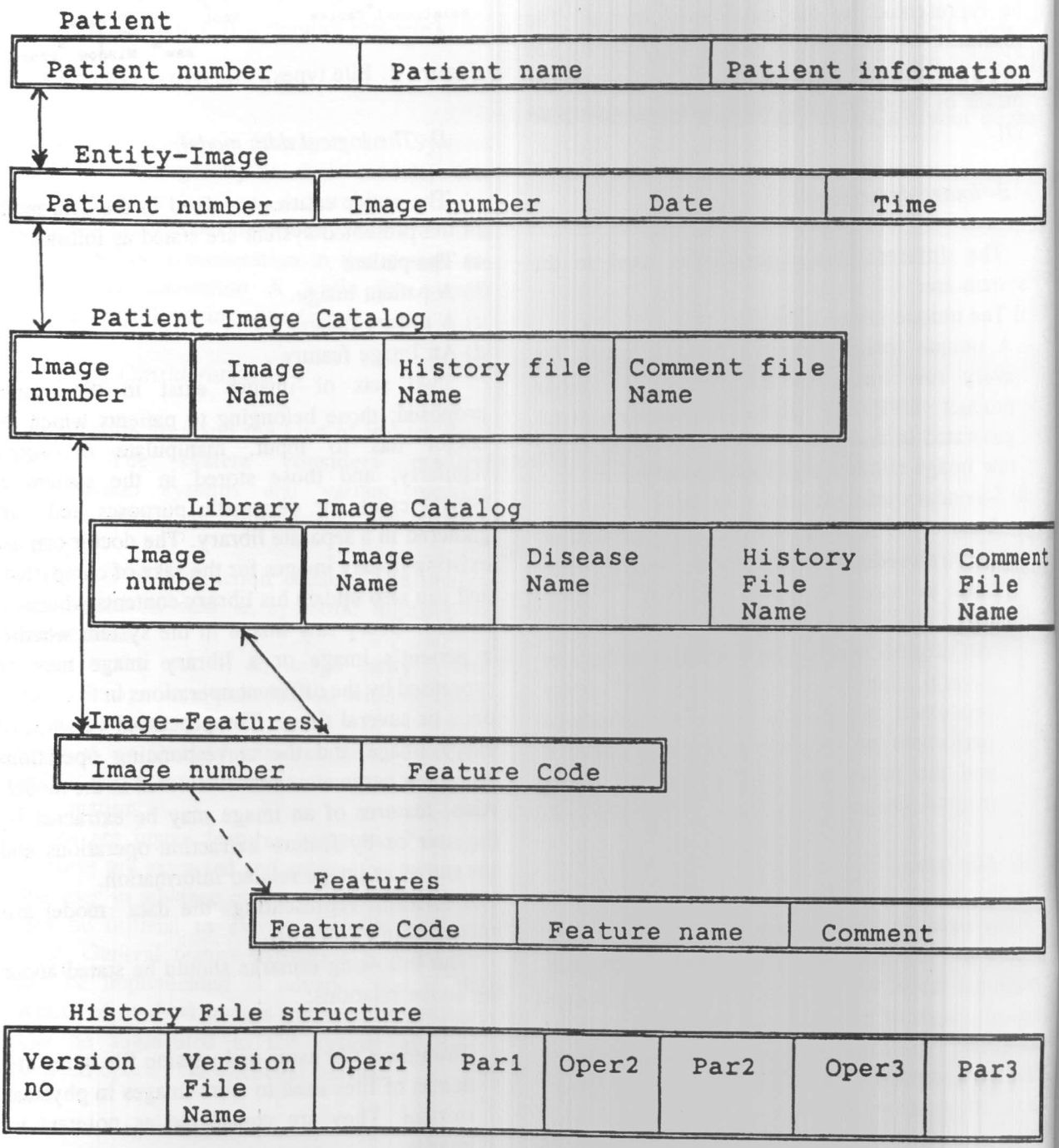

Figure 3. Logical data model.

- The patient image catalog is unique in the system. It contains image related information and pointers to the image file, its corresponding history and comment files in physical storage. We would like to introduce here the image data type which denotes a pointer to an image file and is added to the conventional database types like the character, numeric, logical, date and memo.
- The library image catalog is also unique in the system. It is similar in structure to the patient image catalog but it has an extra attribute which is the disease name of the typical case stored.
- The entity-image relation relates each entity (patient) with its images and facilitates query by date and time.
- The image-features relation relates each image with the features identified in it to facilitate query by image content.
- For the sake of generality the features relation is added in order to accommodate different medical applications. For each application the features detected are different from the other so the user may identify the feature names and give a comment on each in this file then simply use the feature codes in data manipulation and query.
- The patient information is also dependent on the medical application. Thus, in order to accommodate different requirements we have to add a patient information file whose attributes will be identified by the user.
- The history file is a relation corresponding to only one raw image of the system. It contains all the information about the processed versions of the image stored in the system. For example, an image called img1.raw may be thresholded by using a threshold value = 60, so we have an image with version 1 which has oper1= thresholding and par1= 60 while oper2 and oper3 are NULL. IF the thresholded image is further processed by edge detection with par2= 3 ,we get a second entry in the history file with version number 2, oper1= thresholding, oper2 = edge detection and oper3= NULL. Figure (4) shows the example history file for the image img1.raw after storing the two produced images.
- The number of history files in the database is equal to the total number of raw images.
- The comment file name is a pointer to a text file which contains the comments of the doctor on a certain image. The number of comment files in the system is equal to the total number of images in it.

Version no	Version File	Oper 1	Param 1	Oper 2	Param 2	Oper 3	Param 3
1	1.thr	thr	60	NUL	0	NUL	0
2	1.te	thr	60	edg	3	NUL	0

Figure 4. An example history file.

Having covered the logical design of the system in previous Sections, the next Section gives a detail explanation of the system capabilities.

IV- System operations

The operations of the system are divided into the following categories:

1) Input/Output operations:

These operations are further divided into data manipulation and display operations:

i) The data manipulation operations include the following:
- The registration of a new image into the system.
- The addition of a new patient information.
- The modification of an image information or comment file.
- The modification of a patient's information.
- The deletion of a patient image from the system.
- The deletion of a patient from the system.
- Loading an image into the working area.

ii) The display operations include the following:
- Displaying an image together with its comment file on one screen.

- Displaying up to six images on the same screen.
- Listing an image history file which includes the information about all its processed versions.
- Listing the contents of the patient image catalog.

2- Library operations

A library image may be loaded, displayed and its information may be modified by the above operations. However, other operations are only concerned with library images. These are the following:

- Listing library contents.
- Addition of an image into the library.
- Deletion of an image from the library.
- Retrieval of a library image by disease name or conditions on its features.

3- *Pattern recognition and image processing operations*

The PRIP operations presented consider the requirements of a general medical application. A list of these operations follows:

i) Image Enhancement Operations:
Five different techniques are available in the system:

- Local enhancement.
- Contrast enhancement.
- Logarithmic transformations.
- Exponential transformations.
- Histogram equalization.

ii) Image Smoothing operations:
Image smoothing in the proposed system is performed by two different techniques:

- Neighborhood averaging.
- Median filtering.

iii) Image Thresholding:
The image is transformed into a binary one by assigning all the gray levels below a certain threshold value into black and all others into white.

iv) Image Sharpening (Edge detection):
Edge detection is performed by more than one operator. Each operator may be most suitable for certain kinds of images and may be misleading for other kinds. The operators included in the system are:

- Simple gradient operator.
- Robert's gradient operator.
- Sobel's operator.
- Laplacian operator.

v) Contour following:

In this algorithm, the boundaries of the picture are traced after applying an edge detection operator. This operation is useful in image segmentation that aims at dividing the image into meaningful regions.

vi) *Arithmetic/Logic Operations with one image*:

The ALU operations performed on one image that are provided by the system are the following:

- Adding a constant value to the image.
- Subtracting a constant value from the image.
- Anding the image with a constant value.
- Oring the image with a constant value.
- Xoring the image with a constant value.
- Reversing an image.

vii) Arithmetic/Logic operations with two images:

The ALU operations performed with two images that are provided by the system are:

- Adding two images.
- Subtracting two images.
- Anding two images.
- Oring two images.
- Xoring two images.

4) Image Manipulation operations:

The image manipulation operations provided by the system are listed as follows:

- Reducing image size.
- Zooming.
- Window definition.

5) *Statistical operations:*

The statistical operations included in the system are:

- Calculation and display of an image histogram.
- Calculation of the image moments to determine: mean,standard deviation, skewness, maximum and minimum values of an image.

6) User-defined operations:

Each user may define a set of operations that extract certain features from his images or make a series of operations to get a certain effect on an image. He may utilize the image processing operations provided by the system or other user-defined operations to achieve his goals by building a processing package consisting of calls to the sequence of operations needed according to a specific syntax delivered to the user. These processing packages are augmented to the system in a separate user menu.

V- System interface

A system main menu is divided into pull down menus each presenting a certain category of operations. A query may be formulated using two different ways in the system. First, a purely non-procedural menu-driven way by using the system interface. After selecting a certain operation from the menu, the system responds by asking several questions until the query is completely specified.

The second way is by using a command-oriented interactive language. An operation is invoked by writing its command-code followed by other parameters as command line arguments according to a fixed syntax provided in the system.

The user may load an image into the working area. All the operations performed will take this image to be their input image by default until a different one is loaded.

VI- System Implementation

The system is implemented by means of two languages, namely the C language and the Dbase4 language. Dbase4 is the conventional database language which is extended by an interface that deals with the pictorial domains of the query. It is used to create and maintain all the relational tables. Program files are written to perform the operations concerned with these tables such as manipulating secondary information and library contents. Furthermore, there exists a Dbase4 program file for every operation presented in the system. Each operation actually invokes a program file which consists of Database operations that maintain tables and call image processing and display routines which are written in the C language.

Now that the different aspects of the system were presented, a case study will be presented in the following section.

VII- Case Study

A- *Fluorescein angiography fundus imaging:*

The eye fundus images are photographed by a technique called fluorescein angiography. Fundus photography is performed in rapid sequence following intravenous injection of the fluorescein dye. A sequence of images is taken for the eye at different stages of the dye flow which reveal how the dye fills the arteries, capillaries and veins. This study can detect many kinds of eye diseases. The sequence of images taken in one session is called an angiogram. Figure (5) shows a patient angiogram.

The system presented is very useful for an ophthalmologist for storing the patient angiograms at different stages of therapy. Whenever the patient is subjected to lazer treatment, the

angiogram is compared with the previous ones to assess the adequacy of treatment. The database is used to store the patient data as well as angiograms and the operations provided can be utilized for comparison purposes. Furthermore, a library of the variant typical cases of the diabetic retinopathy disease was built as an example for a reference library.

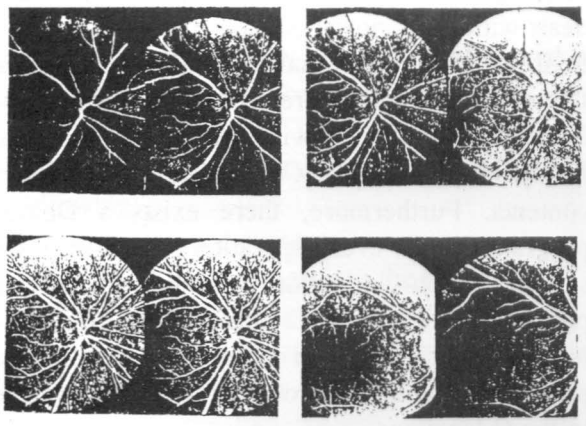

Figure 5. A patient angiogram.

The data model is tuned to any application at installation time. The application dependent relations are:

i- The patient information relation:
This relation structure is modified to:
{name, birthdate, sex, history of disease, laser treatment, visual acuity with correction, visual acuity without correction, complaint, clinical diagnosis}

ii- The patient-image relation:
The eye (left/right) attribute is added to the relation structure to completely specify a patient image. Thus the relation structure becomes:
{image no, patient name, date, time, eye}

iii- The features relation:

This relation is not changed in structure but the user identifies his feature names, codes and gives his comments on them.

B- User-defined operations:

A set of user defined operations may be augmented to the system whenever needed for the specific application. These are supplied in a user menu. The following were implemented for the above case study:

i- Displaying a complete patient angiogram.

ii- Step by step diagnosis: A guide to the doctor in his analysis of fundus images [11].

iii- Exudate extraction program:
A feature extraction routine that detects and measures the amount of exudates which is associated with many eye diseases [12].

iv- Diabetic retinopathy case analysis: By asking several multiple choice questions, the program determines the stage of the disease and gives the suitable treatment.

VIII- Discussion

The design proposed and the operations provided consider the requirements of a general medical PDBMS. The system can be tuned with minimum effort to any application required and application dependent modules can be removed without any effect on the system and others can be augmented which makes the system flexible and easy to expand.

The menu-driven system is very much user friendly and the query is very easy to formulate using the system menus.

The amount of storage needed can be reduced using image compression, size reduction and/or storing user-defined windows of the image if the doctor is interested in parts of the image and not its entirety.

The image history file proposed enables image analysts/users to store several versions of an image generated in the system by means of different PRIP operations together with the operations performed on the raw images to produce them and the parameters used. This facility eliminates the need to perform the same operation on an image more than once thus saving much time because image processing operations

are the most time consuming in the system. It also helps image analysts to utilize an already processed or enhanced image in their analysis.

The features stored as image related data makes the retrieval of images by content much faster than in direct spatial search operation [13] as this operation reduces to just a table lookup process.

The design also provides the facility of building processing packages or command programs that are to extract certain features from the image thus accelerating the time for query formulation and making it easier for users who do not understand the effect of each individual operation to benefit from the system.

Furthermore, the system is implemented as an extension of a widely used and easy to learn DBMS which is the Dbase4 system and both image and alphanumeric data are treated within the same work area. The system is used on a personal computer with an affordable price for a doctor's clinic and can also be connected to a local area network by putting the system on the file server computer and letting other user terminals be connected to it. Thus image communication and sharing can be achieved.

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REFERENCES

[1] R.E.Dayhoff, A Medical Image Database System, *Computers in Health Care*, 39-42, Dec 1988.

[2] H.K Huang, M. Shiu and F.R. Suarez, Anatomical cross-sectional geometry and density distribution database, *Pictorial Information Systems*, S.K.Chang and K.S.Fu, eds, 351-367, Springer-Verlag 1980.

[3] J.Toriwaki, J.Hasegawa, T.Fukumura and Y. Takagi, Pictorial information retrieval of chest X-ray image database using pattern recognition techniques, *Proc. MEDINFO'80*, 1116-1119 1980.

[4] Y.Kanamori, Y.Masunaga, K.Kido and S.Noguchi, Design of a database system for skull line drawings processing in orthodonitics based on the relational model, *Proc. MEDINFO'80*, 1154-1158 1980.

[5] N. Yokoya and H.Tamura, A database system of microscopic cell images, *Proc. ISMIII'82*, 471-476 1982.

[6] M.Kunt, Electronic file for X-ray pictures, *Pictorial Information Systems*, Springer-Verlag, 368-415, 1980.

[7] H.Tamura and Y.Naokazu, Image Database Systems: A Survey, *International Journal of Pattern Recognition 17*, (1), 29-43, 1984.

[8] S.K.Chang, *Principles of pictorial information systems design*, Prentice-Hall, Inc, Englewood, New Jersy, 1989.

[9] R.C. Gongalez and P.Wintz, *Digital Image Processing*, Addison-Wesley publishing company, May 1987.

[10] W.B.Green, Image Database Management, *Digital Image Processing: A systems approach*, VAN NOSTRAD REINHOLD company, 165-180, 1983.

[11] J.W. Berkow, J. S. Kelley, and D.H.Orth, *A guide to the Interpretation of Fluorescein Angiograms*, American Academy of Ophthalmology, California, 1984.

[12] N.P.Ward, S.Tomlinson, and C.J.Taylor, Image analysis of Fundus photographs, *Ophthalmology*, vol 96, no. 1, Jan 1989.

[13] N.Roussopoulos, C. Faloutos, and T.Sellis, An efficient Pictorial Database system for PSQL, *IEEE Trans. on SoftWare Engng*, vol 14, no.5, 639-650, May 1988.