A Medical Image DataBase System for Tomographic Images

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Abstract

In this paper we present initial work on the design and implementation of a prototype Medical Image Database system for tomographic images. Our attention has been focused on techniques for the automated description of anatomical crossections in terms of geometrical features which facilitate matching operations and can be used to access tomographic images by content. These techniques are computationally efficient and the resulting descriptions compact in order to meet the requirements of the fast-paced clinical environment and to minimize storage space. The organization of the image database and possible strategies for image retrieval by content are also described and discussed.

Introduction

It is possible to extend the capabilities of diagnostic medical imaging techniques by developing Medical Image Database (MIDB) systems, which support the storage, retrieval, presentation, and interpretation of medical images. MIDB systems are emerging as an important component of Picture Archiving and Communications Systems (PACS), which in turn must become fully integrated with other components of a Hospital Information System (HIS) in order to support administrative, clinical, teaching, and research activities. Retrieval strategies and user interface designs must take into account the requirements of HIS and PACS as well as the multimedia nature of medical records [1,2]. General issues related to pictorial information systems have been raised previously by other investigators [3,4]. Important considerations in the design and implementation of image database systems are: image feature extraction, image content representation and organization of stored information, search and retrieval strategies, and user interface design. To date, a general methodology for the design of such databases has not been developed. Once the requirements of a particular application have been determined, techniques of image analysis and description, with known database design methods, are adopted to develop an image database which satisfies these requirements [5]. The content of particular images can be determined, based on the correspondence between the derived description of a particular image and some appropriate model(s) of an image class [6]. So far, most of the methods which have been developed are knowledge-based, making use of application and domain-specific knowledge, and are not particularly well suited for image retrieval by content and image database work. This is primarily due to problems with computational efficiency, uncertainty, and knowledge representation [7]. Nevertheless, for certain applications within well specified domains, it is possible to develop and implement techniques of image analysis, symbolic content representation and modeling which can be used to manipulate images in such systems efficiently.

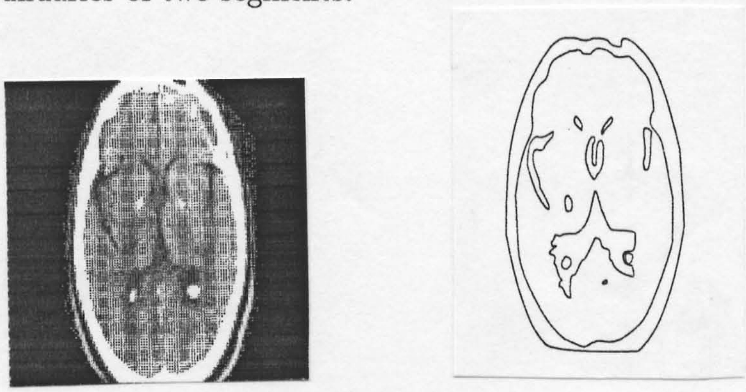
Image data can be viewed as a component of a multimedia document, i.e. a structured collection of image, voice, text, and attribute data [8]. Images together with their descriptions and other document components are stored in a *document base.* Queries on a MIDB must be expressed via a well defined and powerful query language capable of handling different image representations and attributes. To date our attention has been focused on the development of techniques for the automated description of anatomical crossections in terms of geometrical features which facilitate matching operations and can be used to access tomographic images by content. These techniques are computationally efficient and the resulting descriptions compact in order to meet the requirements of the fast-paced clinical environment and to minimize the required storage space. Furthermore, the system which is currently being developed provides a flexible and simple storage scheme which facilitates multimedia document retrieval based on image content and minimizes the dependence on the application domain.

Image Analysis and Representation

Picture descriptions are generally given in terms of properties of objects contained within the picture and relationships among such objects. A picture description may also include properties or attributes of the picture as a whole. The specific properties which are used in picture descriptions can be geometric, statistical or textural, or properties specified in a transform domain. The effectiveness of any scheme for retrieving multimedia documents by pictorial content will ultimately depend on the complexity of picture descriptions and picture class models, used in a particular application, as well as the extent to which such descriptions are integrated with representations of other document components. In developing a prototype MIDB system which permits image retrieval by content, we have chosen to work with tomographic images of high tissue contrast because of their relatively well-structured content and their widely acknowledged clinical significance.

Tomographic images are first segmented using lowpass filtering followed by thresholding, with appropriate thresholds determined on the basis of corresponding histograms. A polygonal approximation to segment edges is then obtained and used to compute a set of geometrical features for each segment (Figure 1). Image analysis can be performed online or interactively under the supervision of an expert. Furthermore, the set of geometrical features can be augmented with modality-dependent characteristic tissue parameters. A processing step prior to any further analysis places each image in standard position and orientation so that subsequent descriptions can be rotation and translation invariant.

The description of each segment in the image is given in terms of properties such as: average pixel value, texture, area, perimeter, roundness, orientation with respect to a reference direction, center of mass, etc. In addition to these properties of individual segments, the following relationships between segments are obtained and used in queries: 1) Relative position: takes the values 1,2, or 3 corresponding to a segment being outside, intersecting, or falling inside another segment respectively. 2) Relative orientation: defined as the orientation of the line connecting the centers of mass of two line segments, relative to a reference direction. 3) Minimum distance: defined as the minimum distance between the boundaries of two segments.



(a) (b)

Figure 1. a) Original image. b) Segmented image.

Image Storage

Images together with their descriptions and other document components are stored in the *"document base"*, which consists of a *"logical"* and a *"physical"* database [9]:

1. The *"logical database"*, is used to store representations of the original images in terms of a set of features extracted by automated or computer assisted image analysis and other attributes. The relational model has been widely used to implement a logical database [10]. An alternative method of storing and manipulating images is based on the object-oriented approach which permits image related data, as well as properties and rules to be represented and manipulated in a uniform way [11]. This method is better suited to handling the semantic content of images with its inherent hierarchical structure.

Our work to date has been based on the relational model and the MIDB system described in this paper has been implemented in a SUN enviroment and using SYBASE. The logical database is organized into the following three tables: a) Table IMAGES contains general information about each image as a whole and has the following attributes: image index, image file name, number of segments, date of image acquisition, patient name, symptoms, diagnosis, physician's comments etc. b) Table SEGMENTS contains descriptions of all segments contained in each image and has the following attributes: image index, segment index, average pixel value, texture parameters, area, perimeter, roundness, orientation etc. It can be easily extended to store other features that are shown to be effective in quickly narrowing down the search space for the purpose of document retrieval by image content in a specific application domain. c) Table RELATIONS contains relations between segments of each image and has the following attributes: image index, first segment index, second segment index, relative position, relative orientation, minimum distance.

A number of different *"views"* can be defined in terms of the above tables, corresponding to classes of specific image/segment properties and relations.

2. The *"physical database"* contains the original image files. Pointers from the logical to the physical database are handled by the MIDB management system. If necessary, image compression techniques may be applied to reduce storage requirements. To date, no image file structure has been introduced in our system and image compression is not implemented. However, images will eventually be stored in clusters based on the likelihood of being retrieved together in responce to a particular query.

Image Retrieval

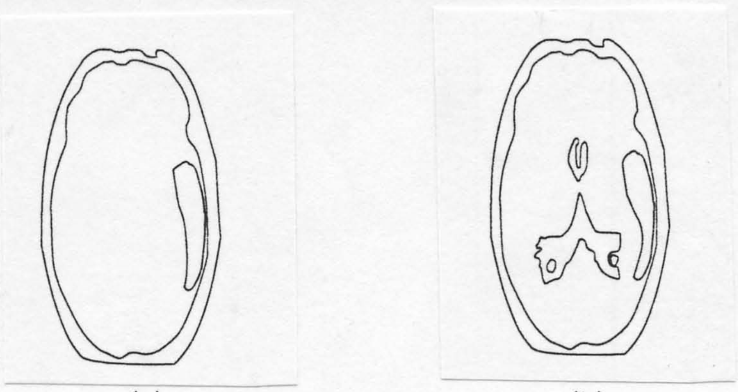
All queries to the MIDB address the logical database rather than the raw image data stored in the physical database. All documents including images that satisfy the search criteria should be retrieved and displayed for viewing. Thus, an efficient method for browsing documents must be provided. Queries may be executed using a command-oriented query language extended to handle image data. There may be substantial uncertainty as to what a user is looking for, whereas a query answer set may be enlarged due to inexact matching techniques. Query formulation needs to be iterative and flexible, enabling gradual resolution of user uncertainty; it must also be associative, exploiting all possible associations between document components. A query based on pictorial content may specify:

1. The semantic content of an image: an image or part of an image is specified by pictorial example. In this case, a sample image or sketch is provided and the system must analyze it, extract its semantic content, create an appropriate representation, and match this representation against representations of images stored in the database. Alternatively the semantic content can be specified directly by a conditional statement involving features and other attributes similar to those stored in the logical database.

2. Various document features/primitives, either general or particular to objects contained in the image: these are specified as image attribute values and relevant images can be better accessed using indexing techniques.

3. Combinations of (1) and (2).

The response to retrievals depends highly on query type, specificity, complexity, completeness of data stored in the database, amount of online image analysis required and the size of the search. Queries must address properly defined classes of stored image information. It is generally useful to define classes corresponding to what queries usually address. Query search is currently performed on the main database tables. Performance can be substantially improved by limiting the search space with the definition of classes. In the most complicated type of query which has been implemented, a sample image or sketch is given and all images that are similar to it are returned. (Figure 2). Similarity is expressed as a weighted sum of differences of specific attributes. Appropriate thresholds are used to define the required degree of similarity.



(a) (b)

Figure 2. a) Query image. b) Example of retrieved image.

Conclusions and Future Directions

An approach has been presented for the organization of a prototype MIDB system. The performance of image analysis and retrieval techniques has been evaluated on the basis of a limited number of images and the results are encouraging. Our immediate target is to test more sophisticated image description and retrieval methodologies and to investigate object-oriented techniques. An intelligent user interface must be developed for handling user uncertainty by iterative and flexible query formulation. A repertoire of alternative image analysis and modeling techniques to choose from must be provided in an attempt to minimize the complexity of picture descriptions and modeling in a particular application domain.

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