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Content-based Retrieval of Medical Images

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***Abstract*—**With the advance of multimedia and diagnostic images technologies, the number of radiographic images is increasing constantly. The medical field demands sophisticated systems for search and retrieval of the produced multimedia document. This paper presents an ongoing research that focuses on the semantic content of radiographic image documents to facilitate semantic-based radiographic image indexing and a retrieval system. The proposed model would divide a radiographic image document, based on its semantic content, and would be converted into a logical structure or a semantic structure. The logical structure represents the overall organization of information. The semantic structure, which is bound to logical structure, is composed of semantic objects with interrelationships in the various spaces in the radiographic image.

***Keywords*—**Semantic Indexing, Content-Based Retrieval, Radiographic Images, Data Model

I. Introduction

RADIOGRAPHIC images such as Computer Tomography (CT), Magnetic Resonance Images (MRI), X-rays, and sonograms are common ways to diagnose diseases. With the advances of multimedia technologies in general and diagnostic images technologies specifically, the number of radiographic images is constantly increasing in the biomedical field. While the digital medical images are increasing, their effective processing is still limited. In particular, the retrieval of medical images based on their content is still difficult. Therefore, effective and efficient access to image information, based on their content, has become an important field for researchers.

Many content-based image retrieval methods were applied to medical images. Current images retrieval systems allow users to browse and explore visualized patient data, but offer little assistance in interpreting what is being displayed [13]. The semantic gap, the difference between the limited visual image features and the abundance of user semantics [16], is particularly important in medical images. Important features in the design and implementation of the content-based retrieval system are image content extraction, representation, search and retrieval strategies, and user interface design. To date, a general and comprehensive data model for storing the semantic content of radiographic images in databases has not been developed. Once the requirements of a particular application have been determined, techniques of image analysis and description, with known database methods, are adopted to develop an image database which satisfies these requirements [9]. This short paper describes an ongoing work on developing a structured data model to capture the semantic content of radiographic images for later retrieval.

II. Related work

Radiographic images indexing is the continuation of ongoing research of image understanding and content-based image retrieval (CBIR) of biomedical images [5, 6, 8, and 11].

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Such systems retrieve relevant images based on visual content such as color, texture and shape. Semantic indexing of images is another area of research addressed by a number of work [7, 10, and 15]. Natural language processing (NLP) techniques have been applied to radiology reports to extract salient terms [1, 2, 12, and 14].

This work focuses on developing a comprehensive conceptual model for describing the semantic content of a radiographic image document and relevant information about this content. Patient record model were proposed in [17, 18, and 19]. These work focus on semantic objects and properties while neglect the different relationships between semantic objects.

III. Strategy of Solution

A great deal of effort has been put into image retrieval, but the main question that needs to be asked is how a radiographic image retrieval system can be developed if a radiographic image document is not understood. It becomes evident here that a diverse model to represent the different aspects of the information contained is needed.

To develop a semantic content-based radiographic image retrieval system, it is necessary to follow this procedure:

- Develop a formal description for semantic radiographic image content;
- Set indexes that are efficient in terms of storage and search time, conforming to the human perspective and address as much information as possible in a radiographic image document;
- Study the capability of existing signal processors and the method of integration with the proposed semantic model to maximize procedures that can be automatically conducted;
- Develop an efficient structure for the semantic radiographic image acquisition and retrieval in light of the proposed semantic model;
- Design querying methods for radiographic image documents that meet human needs;
- Eliminating semantic and schematic heterogeneity between query content and radiographic image content.

IV. Semantic Radiographic Image Model

At the semantic level, a radiographic image document is an *unstructured* media type. Physically, a radiographic image is a series of pixels. A fundamental task in the semantic radiographic image modeling is to identify a conceptual structure of a radiographic image document known as *radiographic image semantic structuring.*

According to Open Document Architecture [3] and Standard Generalized Markup Language (SGML) [4], a document has two conceptual structures:

- The logical structure represents the overall organization of information.
- The layout structure represents the presentation of a document on a screen or a paper which is automatically related to the logical structure

Semantic structure is a third structure proposed by this paper. The structure is bound to the logical structure and expresses the meaning of the content of the logical elements.

A. Radiographic image Conceptual Layers

To capture the radiographic image conceptual structure, a sample of user queries generated by radiologists was analyzed in the biomedical field.

Some examples of the constructed queries include:

"Retrieve radiographic images of chest x-rays performed on patients over 40 years old after 1/6/2009"

"Retrieve radiographic images with enlargement of the right ventricles"

"Retrieve radiographic images of 50-year-old patients with lung cancer"

"Retrieve radiographic images of Stage III lung cancer"

With a preliminary analysis of the entire sample set, the paper proposes the following conceptual model for radiographic images. The model is composed of physical, semantic and logical layers. The semantic layer and a logical layer are built on top of the physical layer of a radiographic image to provide a semantic abstract view of the image content. Semantic content-based image retrieval does not work with the physical layer directly, but with the semantic layer and the logical layer.

Layers proposed for the radiographic images are described as follows:

1.*Physical layer* is the raw data which contains objects.

2.*Semantic layer* is an abstract layer in which the physical layer's contents are linked into the real world using medical ontology. It represents the meaning of those physical objects. The levels of semantic layers are referred to as intermediate and high-level.

a. *Intermediate level* semantics are directly extracted from the physical layer. These are the elementary objects, perceptual features and spatial associations. This is achieved by mapping salient terms to the UMLS Metathesaues. The intermediate level can be used to answer clinical questions such as 'Find a lung'.

b. *High-level* semantics are composed of intermediate level content. In the proposed semantic model, composite units, high-level descriptions and contextual associations are considered high-level semantics. Ontology knowledge representation and inference rules are needed to detect high-level semantics. High-level can be used to answer clinical questions such as 'Find Choroid plexus cyst'.

3. *Logical Layer* is composed of units, each constructed from units from the semantic layers. The logical layer is used to answer clinical questions such as, 'Find a 25-year-old male diagnosed with lung cancer'.

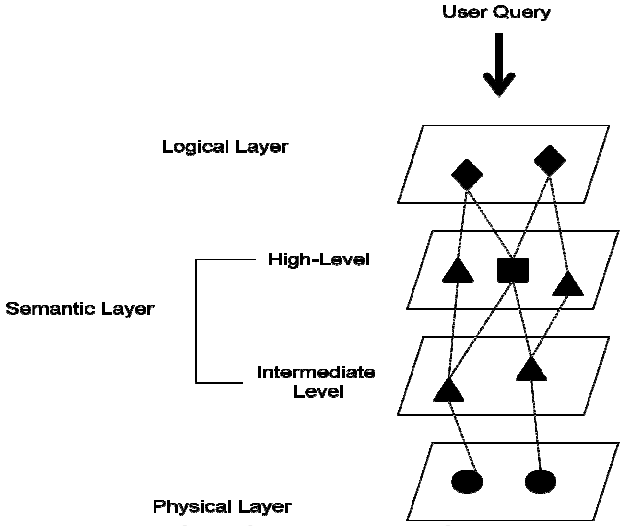

Fig. 1 Radiographic image Conceptual Layers

B. The Conceptual Model

Semantic content-based radiographic image retrieval is the selection of an image from a collection of radiographic images on the basis of their content description. The first step toward developing a semantic content-based radiographic images retrieval system is the development of a formal conceptual modeling of radiographic images content description.

The proposed model is based on the consideration of the radiologist's description of a radiographic image. A user view of a radiographic images document is the perception of the proposed image's content. Understanding the user view helps decides what aspects of the radiographic images should be considered and stored. This will enable the proposed model to depict the user's various perspectives of a radiographic images document. The document will then help develop a system capable of answering the user's heterogeneous queries.

Based on the aforementioned samples of queries collected and analyzed, the user could reveal different perspectives, depending on meaningful entities and descriptions of interest that exist in a conceptual structure. In addition, semantic units in a radiographic image document are related to each other in the image space, contextual space and logical space. The user may refer to a semantic unit based on its relationship with another; e.g. radiographic images of 'cyst formed *behind* the knee versus a cyst as *part-of* the brain.

The proposed semantic model is represented by semantic units, descriptions and associations. This section focuses on the provision of an elaborate semantic model to describe the semantic content of images. The model addresses the semantic structure, the high-level semantics composition and the content indexing.

End users often have a fuzzy understanding of their own need. Fuzzy needs could be expressed with a number of possible interpretations or representations. Therefore, *abstraction* is an important mechanism for imitating the user view of radiographic image content in that it associate a physical element with a real world concept.

The content of the radiographic images is usually meaningful when associated with secondary information related to patient demographics, procedures and information

provided by domain experts following the analysis of the images. This information is represented by logical structure.

As a conclusion, we use two complementary structures to represent the information related to radiographic images. These are logical and semantic structures. In radiographic images, the semantic structure is embedded in logical components.

1. Structure

The logical structure represents the overall organization of the medical domain's radiographic information. By studying the radiographic image report documents generated by domain experts and analyzing the potential queries, the author suggested the following logical elements to represent the appropriate structure of a radiographic image.

- Patient Demography: An example would be the patient's properties such as age and gender.
- Clinical Procedure: Procedure with properties modality, date, time and type which are requested by a physician, radiologist, or medical institute.
- Symptoms: Store the observations made including the anatomical location
- Diagnosis: Store the identification of the disease.
-

2. Semantic Structure

The proposed semantic radiographic image model is based on the human perspective in order to have a system that could retrieve clips capable of answering human query. Hence, the conceptual model based on the user view constitutes:

- Semantic units
- Associations among semantic units
- Descriptions of semantic units and associations
- Logical component
- Abstraction mechanisms over semantic units, descriptions and associations.

The semantic interpretation of medical images needs knowledge bases. The following example that describes how our proposed system intent to interpret radiographic images:
A physician enters an x-ray. CBIR automatically identify some logical components such as image type "x-ray", patient age "40", gender "Male", and some physical objects. The meaning of these extracted objects is defined using a medical ontology and interpreted into intermediate semantic level units such as "brain" and "cyst" and spatial relationship "contain". With the use of knowledge-base, these semantic units on the intermediate level can be interpreted into a higher level abstracted semantic units "Choroid plexus cyst". All the above extracted semantics are stored as indexes to answer query such us "Retrieve an X-ray image for a 40 years old male with Choroid plexus cyst".

V. The General Architecture of Prototype

The system must offer access to medical images based on their content. In order to do so, the system should allow the storage, the management, the indexing and the retrieval of the multimedia documents. The architecture of the proposed system is described in figure 2 below. For a content-based retrieval of multimedia document, a comprehensive data model to describe the content of the documents and an exhaustive language to describe the content is needed. An index language is exhaustive if all the concepts of a document are directly represented [20]. Our above proposed model aimed at capturing and representing all the concepts that may appear in a radiographic image document and the possible relationships linking these concepts in the different spaces (spatial, contextual and semantic).

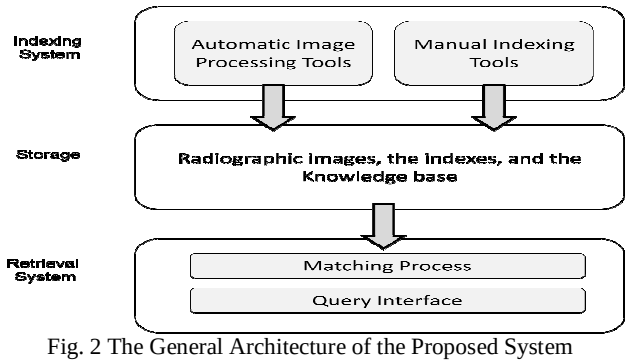

Fig. 2 The General Architecture of the Proposed System

The architecture stores multimedia radiographic images as well as their indexes in a DBMS for content storage, retrieval and management. In addition, the system provides indexing and retrieving sub-systems.

The Indexing component extracts the semantic content of the images. Intermediate level semantics can be directly extracted from the physical layer using image processing techniques. High level semantics can be formed semi-automatically using knowledge based system. The assignment of semantic units to some logical components can be achieved automatically, for instance clinical procedures can be automatically extracted from the DICOM images, while other manually. The retrieval component accepts and process queries based on the content of the multimedia documents.

VI. Conclusion

This paper described an ongoing research that attempts to emulate radiologists understanding of the semantic content of a radiographic image and consequently develop a formal semantic model for radiographic image content and semantic retrieval. The proposed model allows associations to be defined over semantic units and logical units in order to develop high-level semantics. Another extension allows for the application of abstraction mechanisms to any type of semantic unit, description or association unlike other models which can be applied only to objects. A future work will be developing a prototype to test the efficiency and precision of the proposed model.

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