Content based image retrieval in medical applications: an improvement of the two-level architecture

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Content Based Image Retrieval in Medical Applications: An Improvement of the Two-Level Architecture

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Abstract: **Medical imaging is specific part of medicine according to the medical images features. This is the reason for growing up requirements for improvement of Content Based Image Retrieval (CBIR) systems applied on medical images. Improving these systems is one of the biggest challenges for scientists in this domain. In this paper we propose an extension and improvement of the existing two-level CBIR architecture proposed in [1]. The proposed improvement of the two-level architecture is expected to increase the accuracy of the retrieval results.**

***Index Terms*: Content Based Image Retrieval (CBIR), Digital Imaging and Communications in Medicine (DICOM), archiving and communication systems (PACS), medical images.**

I. INTRODUCTION

The continuously increasing amount of medical images initiates the necessity for designing precise systems that allow effective storing and indexing those images. Improving techniques for content based analyses and retrieval for large digital medical image databases is one of the biggest tasks.

The annual production of the large radiology centers is approximately ten Terabytes per year [2]. Implementing computer techniques for efficient indexing, automated processing and relevant retrieval requires developing effective, fast and accurate decision support tools. The use of such tools should be done carefully due to the particular characteristics of the domain of interest.

Due to the importance of medical imaging, the Digital Imaging and Communications in Medicine (DICOM) [3] standard is created by the National Electrical Manufacturers Association (NEMA) [4]. The aim of this standard is precise handling, storing and transmitting digital medical images. Additionally, DICOM defined Information Objects not only for images but also for patients, studies, reports, and other data groupings. The goals of DICOM are to achieve compatibility and to improve workflow efficiency between imaging systems and other information systems in healthcare environments worldwide. DICOM is used or will soon be used by virtually every medical profession that utilizes images within the healthcare industry. These include cardiology, dentistry, endoscopy, mammography, ophthalmology, orthopedics, pathology, pediatrics, radiation therapy, radiology, surgery, etc [5].

Moreover, DICOM can be used to facilitate the development and expansion of the picture archiving and communication systems (PACS) [6], namely, computer systems that include image storage, retrieval, distribution and presentation.

DICOM supports interconnections of PACS modules from different vendors, e.g. for post-processing of the images and their annotation with alphanumerical attributes such as patient and study information, image descriptions, and diagnostic reports. This textual information, which is stored within the DICOM header, is currently the only means to access and retrieve medical images from the PACS archive [7].

In this paper, we present an improvement of the two-tier CBIR architecture applied for brain MRI images. Section 2 presents an overview of various Content Based Image Retrieval (CBIR) systems. Section 3 contains an overview of CBIR systems developed for medical purposes and in section 4 we propose an improvement of the existing two-tier CBIR architecture. Section 4 includes conclusions.

II. AN OVERVIEW OF CONTENT BASED IMAGE RETRIEVAL SYSTEMS

In all CBIR systems images are represented by the appropriate feature vector in a feature space. Such feature vector gives meaningful information of the image properties. This vector plays an important role in the phase of retrieval, as well. The main goal here is to provide relevant result to the user. Additionally, from the distance between images in the feature space, a similarity measure between images is defined.

The general architecture of CBIR system proposed in [8] is depicted in Fig1.

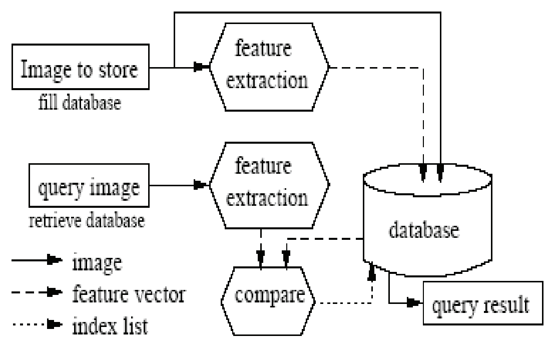

Fig.1 – General architecture of CBIR systems.

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Given a query image, a system first extracts image feature vector and then compares it to feature vectors of the images stored in the database. This way, it can rank images of the database according to the distance of their feature vector to the query one. This ranking is the query result [9].

Different kinds of CBIR systems have been proposed and used. The earlier systems do not include any semantic level and use only low level features, namely, color, texture and shape. These systems include QBIC (Query By Image Content) [9] [10], Virage [9] [11], Photobook [9] [12], VusualSEEK [9] [13], Mars (Multimedia Analyses and Retrieval System) [9] [14], etc. QBIC (Query By Image Content) [9] [10] is the first and very famous CBIR system proposed by IBM, and Virage [9] [11] is a commercial CBIR used by CNN.

Blobworld [9] [15] is another CBIR system which, includes a segmentation phase in the query process. The goal of including this phase, based on color, position and texture features in the case of Blobworld, is to involve high level information.

III. CONTENT BASED MEDICAL IMAGE RETRIEVAL SYSTEMS

CBIR systems are widely used in medical imaging. The aim is to provide relevant support in medical imaging diagnosis.

The objective of CBIR in the radiology information systems is to give the right information to the specialist in the appropriate time, to improve the quality and efficiency of the diagnoses. In the process of clinical decisions, CBIR offers great benefits, being able to retrieve images in databases of the same form, anatomical region and pathology [16] [17].

The very specific characteristics of the medical image content require a specialized design of CBIR systems. In that manner, a variety of information provided by the different types of medical image acquisition devices and technologies such as magnetic resonance imaging (MRI), magnetic resonance spectroscopy (MRS), computed tomography scanners (CT), single photon emission computer tomography (SPECT), positron emission tomography (PET), electrical impedance tomography (EIT), ultrasound probes (US), need to be adequately analyzed.

CBIR systems can be used for searching and retrieving different kinds of medical images from large databases on the bases of the visual content of the images. Thus the precise retrieval from the large medical images collections can be accomplished by indexing or feature extraction, namely, by describing the images. So the phase of making appropriate description of the medical image content is very important to achieve accurate, efficient and correct retrieval process.

To provide accuracy and relevance in the process of medical image retrieval some specialized CBIR for medical purposes has been proposed.

One such system that uses images by High Resolution Computed Tomography (HRCT) of lung is Automatic Search and Selection Engine with Retrieval Tools (ASSERT) [18]. For this system two phases of the operation are characteristic: the image archiving and the image retrieval phase.

Another CBIR system for medical images is CasImage, which has been integrated into a PACS environment, containing a teaching and reference database and the medGIFT retrieval system [19] [21]. The images stored in the image database are obtained from different modalities such as MRI, CT, radiographs.

Another system developed as a platform for content-based medical image retrieval is IRMA system. The process behind IRMA includes categorization, registration, feature extraction, feature selection, indexing, identification and retrieval [20] [21].

A two level CBIR platform intended for brain MRI retrieval is proposed in [1]. The two levels provide both generic similarity and semantic information related to special characteristics. The first pre-attentive tier (parallel feature map generation), is concerned with a ”general” description of the images, while in the second, a serial analysis of specific regions of interest is performed. The user can chose to use one of the two levels for retrieval, or a combination of them.

IV. AN IMPROVEMENT OF THE TWO-LEVEL CBIR ARCHITECTURE

A content of medical images involves difficulties in the process of image indexing and retrieval according to the image resolution, contrast and signal to noise ratio. This is the reason why continuous improvements in the design of the content based medical image retrieval systems are always required.

The two-level CBIR architecture includes two main phases [1]:

- The import stage where an autonomous agent searches for images and imports them in the DB (process a) followed by feature extraction and storage (process b).
- The retrieval stage where the user request (c), is followed by the feature extraction from the Query Image (d). The access to the DB and feature comparison follow (e), then the voting stage (f), and finally the presentation of the results to the user (g). The retrieval result is updated as more images from the DB are analyzed, until the user is satisfied or all the DB images are compared to the query [1].

Each agent [22] has its own database used for extracting, retrieving and storing information. Summarizing the results from the asynchronous parallel processes for retrieval decision task is made by the selected voting scheme.

The architecture is depicted in Fig.2.

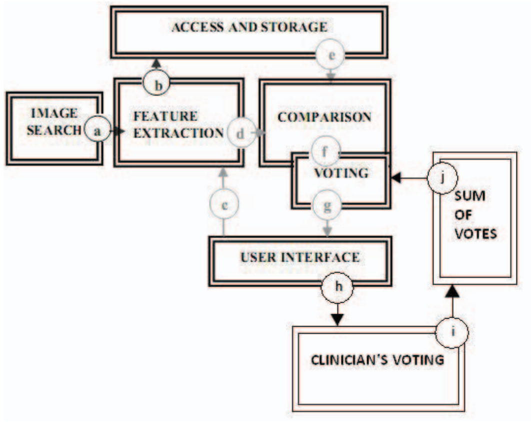

Fig.2 – Schematic view of the platform's function with an extension.

After the process of continuously searching for images and importing those images in the database by the application specific agent (brain MRI in this case), the two phases of the existing architecture follows: computing generic image similarity and computing and analyzing semantic features. Each agent has its own database used for extracting, retrieving and storing information. Summarizing the results from the asynchronous parallel processes for retrieval decision task is made by the selected voting scheme ending with the similarity score calculation [1]:

$$S = \sum_{i}^{P} w_i \frac{a_i}{\sigma(a_i)} \qquad (1)$$

where P is the number of agents in the particular decision group, a is the feature distance vector for a specific query image, w_i is the agent' weight vector and $\sigma()$ – the variance of the respective values in the retrieval set for normalizing the computed values among the different agents. The next stage is the stage which we propose as an extension. According to the fact that MR image retrieval is very specific part of the decision making process, the mixture of the agents' voting and clinician's voting is expected to lead to more precise results. Namely, for the first x% of the retrieved images (x is given by the user or adaptively computed) the clinician gives his vote:

$$f = \frac{1}{n} \qquad (2)$$

where $n = 1, \ldots, X$, where X is the number of the first x% of the retrieved images, and f denotes the distance factor of n-th image to the query image according to his opinion (process h). The sum of the clinician's voting and the agents' voting is then calculated (process i). This new values are then taken as votes and they are considered as the agents' votes again in the phase of voting (process j).

The proposed phase of the two-layer CBIR architecture where the clinician's opinion in terms of votes is involved is expected to improve the relevance of the retrieval results.

V. CONCLUSION

The domain of medical imaging as a specific part of medicine is very convenient environment for using variety of CBIR systems. The main reason is the necessity of effective content based analysis, extracting clinically relevant features out of the image and successful retrieval.

Different CBIR systems already exist. Applying image analyses and retrieval in the domain of medicine requires specific design of content based image retrieval systems. In this paper we proposed an improvement of the two-level CBIR architecture. The phases where the clinician's voting is included and added to the previously computed agents' voting are proposed to increase the accuracy of the retrieval results and the efficiency of the entire system in general.

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