CONTENT BASED IMAGE RETRIEVAL SYSTEM FOR MEDICAL DATABASES

PhD Summary

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1. IMAGE RETRIEVAL
With the development of Internet and the availability of efficient image capturing devices such as digital cameras, image scanners and high-capacity public networks, cheap storage; the size of digital image collection is increasing rapidly. There is desperate need of image searching, retrieval and browsing tool by the users from various domains including remote sensing, fashion, publishing, crime prevention, medicine, architecture etc. To accomplish this above said task many general purpose image retrieval systems have been developed. Basically they are divided into two frameworks i) Text based image retrieval ii) Content based image retrieval.

1.1 TEXT BASED IMAGE RETRIEVAL
In early image retrieval systems, the multimedia or images were manually annotated with text and textual queries were used as the basis for multimedia or image retrieval. These text strings can either be related to a feature in the image itself, or to the image (e.g., object name, place, data of incidence etc.). These strings are stored and can be searched in a structured way, as in structured query language (SQL). But there were significant problems which are due to the high cost of manual text annotation for huge collections and also the lack of information that can be captured easily in the text. These difficulties of indexing, matching and retrieval multimedia information have led to the development of various techniques of image retrieval.

1.2 CONTENT-BASED IMAGE RETRIEVAL (CBIR)
Content-based image retrieval is the application of computer vision techniques to the problem of digital image search in large databases. During the last several years; CBIR emerged as powerful tool to efficiently retrieve
images visually similar to query image. The basic idea behind this approach is representation of image as feature vector and to measure the similarities between the images with distance between their corresponding feature vectors according to some metrics. The finding of correct features to represent images with, as well as the similarity metric that groups visually similar image together, are important milestone in construction of any CBIR system.

In Content-based image retrieval, the images are indexed by their visual contents, such as color, texture, shape, structure, motion and combination of these.

2. CONTENT-BASED MEDICAL IMAGE RETRIEVAL (CBMIR)

The importance of medical image in healthcare is constantly growing, making healthcare more effective and patient friendly. With innovative imaging technology; diseases can be detected earlier with more precision, they can be treated more specific, less invasive and the beneficial result can be closely monitored. The number of digitally produced images are expanding strongly in various departments like radiology, endoscopy, dermatology, MRI, HRCT, X-rays, cardiology etc. The management and the access to these digital medical images repositories become increasingly complex. Most of the accesses to these systems are based on the patient identification or study characteristics like description, modality.

Digital medical images can also be retrieved as text-based and content-based methods. So far, a variety of medical image retrieval systems have been developed using text-based or content-based methods or with a combination of these methods.

2.1 EXISTING CONTENT-BASED IMAGE RETRIEVAL SYSTEMS IN MEDICAL APPLICATIONS

- PACS (picture archiving and communication system).
- IRMA (image Retrieval for medical Applications).
- SPIRS (Spine Pathology and image Retrieval System).
- MIMS (spine x-ray images in the sagittal plane).
- Image Map.
- ASSERT (Automatic Search and Selection Engine with Retrieval Tools).
- WebMIRS system.
- CervigramFinder system
- SPIRS-IRMA system.

3. TECHNIQUES FOR FEATURE EXTRACTION

Image features may be derived from visual cues contained in an image. They are represented as alpha-numeric data in different formats such as vectors or graphs, which stand as compact surrogates for the visual context. One can distinguish two types of visual features: i) Photometric features exploit color and texture cues and they may be derived directly from raw pixel intensities, ii) Geometric features, on the other hand, make use of shape-based cues.

3.1 Shape

A shape descriptor is some set of numbers that are produced to describe a given shape feature. A descriptor attempts to quantify shape in ways that agree with human intuition and these descriptors are in the form of a vector. Commonly used shape based techniques are:

**Fourier Descriptor**: Fourier Descriptor (FD) is an old technique but still considered as a valid description tool. The shape description and classification using FD either in contour or regions are simple to compute, robust to noise and compact. FD is obtained by applying Fourier transform on a shape signature that is a one-dimension function derived from shape
boundary coordinates. The normalized Fourier transformed coefficients are called the Fourier descriptor of the shape.

**Wavelet Transform:** A hierarchical planar curve descriptor is developed by using the wavelet transform. This descriptor decomposes a curve into components of different scales so that the coarsest scale components carry the global approximation information while the finer scale components contain the local detailed information. The wavelet descriptor has many desirable properties such as multi-resolution representation, invariance, uniqueness, stability, and spatial localization.

**Region-based Fourier Descriptor:** The region-based FD is referred to as Generic FD (GFD), which can be used for general applications. Basically, GFD is derived by applying a Modified Polar Fourier Transform (MPFT) on shape images. In order to apply MPFT, the polar shape image is treated as a normal rectangular image. In first step, the approximated normalized image is rotated counter clockwise by an angular step sufficiently small. In second step, the pixel values along positive x direction starting from the image centre are copied and pasted into new matrix as row matrix. In the third step, step first and second are repeated until the image is rotated by 360°. The result of these steps is that an image in polar space plots into Cartesian space.

### 3.2 Texture

Textures are complex visual patterns composed of entities, or sub patterns that have characteristics such as brightness, color, slope, size etc. The texture in an image can be regarded as a similarity grouping. Extraction of feature in image texture analysis is a technique to compute a characteristic of digital image that is able to numerically express its texture properties.

**Autocorrelation Based Texture Features:** The textual character of an image depends on the spatial size of texture primitives. Large primitives give rise to coarse texture and small primitives give fine texture. An autocorrelation function can be evaluated that measures this coarseness.
This function evaluates the linear spatial relationships between primitives. If the primitives are large, the function decreases at a snail’s pace with increasing distance whereas it decreases swiftly if texture consists of small primitives. However, if the primitives are periodic, then the autocorrelation increases and decreases periodically with distance.

**Co-occurrence Matrices Texture Features:** Statistical methods use second order statistics to model the relationships between pixels within the region by constructing Spatial Gray Level Dependency (SGLD) matrices. A SGLD matrix is the joint probability occurrence of gray levels \(i\) and \(j\) for two pixels with a defined spatial relationship in an image in terms of distance \(d\) and angle \(\theta\). If the texture is coarse and distance \(d\) is small as compared to the size of the texture elements, the pairs of points at distance \(d\) should have similar gray levels. It is converse in case of fine texture, if the distance \(d\) is comparable to the texture size, then the gray levels of points separated by distance \(d\) should often be quite different, so that the values in the SGLD matrix should be spread out uniformly. A good way to analyze texture coarseness would be, for various values of \(d\), there should be some measure of scatter of the SGLD matrix around the main diagonal.

### 3.3 Color

For image representation, color is an important feature, and it is widely used in image retrieval. Once the color space is specified, color feature is extracted from image or regions. The most commonly used color extraction techniques are:

**Color Histogram:** The color histogram is representation of bins where each bin is used to denote the probability of pixels in the image being of particular color. Another technique is local color histogram in which the image is segmented into blocks, and then color histogram of each block is obtained. Since the local color histogram compares regions in the same location only; when the image is translated or rotated, so it does not work well. To overcome this problem, one can use the color moment of an image.
**Color Moments:** Color moments are one of the simplest features and are used in various image retrieval systems. The common moments are mean (average color value in an image), standard deviation (square root of the variance of distribution) and skewness (measure of the degree of asymmetry in the distribution). Usually they are calculated for each color component separately. The color moment method’s drawback is that the moments are not enough to represent all the color information of an image.

**Color Coherence Vector (CCV):** CCV incorporates spatial information into the basic color histogram. Each histogram bin is partitioned into two types: coherent and non-coherent parts. The coherent component represents those pixels which are spatially connected and the non-coherent component includes those pixels that are isolated. As CCV captures spatial information; it usually performs better than color histogram.

4. **TECHNIQUES USED FOR COMPARISON**

Medical systems often use measurement approaches such as Euclidean vector space model or measuring distances between a query image (represented by its features) and possible results; representing all images as feature vectors in an n-dimensional vector space. Several other distance measures also exist for vector space model such as the city block distance; the Mahalanobis distance or a simple histogram intersection. Still, the use of high-dimensional feature spaces has shown to cause problems and great care needs to be taken with the choice of distance measurement in order to retrieve meaningful results.

These problems with a similarity definition in high-dimensional feature spaces are also known as the curse of dimensionality and have also been discussed in the domain of medical imaging.

5. **CHALLENGES IN CBMIR**

The amount of visual data produced in medical field shows the importance of developing new and alternative access methods to complement text.
CBIR techniques could be valuable to doctors in assessing medical images by identifying similar images in large archives that could assist with decision support. However, the incorporation of this technology to solve practical medical problems is a goal yet to be realized. Some of the open research issues to the use of CBIR in medicine are identified as:

- Due to the steadily increasing amount of medical image data, fast feature extracting and indexing techniques are needed that simultaneously narrow the gap between the numerical nature of features and the semantic meaning of images.

- The lack of interaction between medical and engineering experts, which is strongly related to usage and performance characteristics of CBIR systems and there is Semantic gap between low level features that are automatically extracted by machine and the high level concepts of human vision and image understanding.

- One of the challenges differentiating medical CBIR from general purpose multimedia applications is the granularity of classification; this granularity is closely related to the level of invariance that the CBIR system should guarantee.

- The combination of visual information retrieval with semantics and free text, the inclusion of the large amounts of medical data into the retrieval process and case-based retrieval, so as not to find similar images but rather similar cases.

- The shape-based descriptors are likely to be useful to fulfil the fine detail requirement of medical image retrieval. However, most of the current medical CBIR systems do not exploit the full potential of the shape information as they either use indirect correlates of the shape cue which are incapable of capturing the required classification granularity.
• The lack of evaluations of the retrieval quality of CBIR systems becomes apparent along with the unavailability of large image databases free of charge with defined query topics and standards.

6. OBJECTIVE OF RESEARCH WORK
Content-based medical image retrieval has the potential to become a very important factor in clinical medical data management. The objective of this research is to develop and implement new approaches of Content-based image retrieval for large medical databases using low-level features such as color, shape and texture that will help to:

• Perceive medical images similar to a human.

• Accurate and efficient retrieval of medical images of particular interest those are similar to a query image. Content-based image retrieval (CBIR) techniques could be valuable to medical practitioners in assessing medical images by identifying similar images in large archives that could assist with decision support.

• Remove both sensory and semantic gap. Visual features are classified into primitive features such as color or shape, logical features such as identity of objects shown and abstract features such as significance of scenes depicted. Still, all currently available systems only use primitive features unless manual annotation is coupled with the visual features. Even systems using segments and local features such as Blobworld are still far away from identifying objects reliably. No system offers interpretation of images or even medium level concepts as they can easily be captured with text. This loss of information from an image to a representation by features is called the semantic gap. The semantic gap can be considered to be a break or discontinuity in the aspect of image understanding, with “human understanding” on one side of the gap and “machine understanding” on the other. Another gap is the sensory gap that describes the loss between the
actual structure and the representation in a digital image.

- Improve classifiers. The medical image classification is an important issue for computer-aided diagnosis. Traditionally medical images have been classified by experts. Classifiers can be used as a pre-processing step to narrow the search space in CBIR systems. The classifier can serve as an automatic medical image annotation tool on its own. It can thus be used to retrieve similar images on a coarse level, e.g., a skull MRI would retrieve other skull images in the database. Problem related to medical image classification is new and challenging due to great imbalance between classes, visual similarities between some classes, variety in one class and difficulty to define discriminative of visual features.

7. THESIS ORGANIZATION

The thesis is organized as follows:

Chapter 1  Introduction
Chapter 2  Literature Survey
Chapter 3  Content Based Image Retrieval System for Medical Databases (CBIR-MD) - Lucratively Tested On Endoscopy, Dental and Skull Images
Chapter 4  Eradicating Semantic Gap with the Help of Image Quality Assessment
Chapter 5  CBIR-MD/BGP: CBIR-MD System Based On Bipartite Graph Partitioning
Chapter 6  A Framework For Medical Image Retrieval Using Local Tetra Patterns
Chapter 7  Conclusion and Future Scope

Chapter 1, started with Image Retrieval System in closer details, covering their specific characteristics and types. This is followed by a brief overview of the application of CBIR. These applications serve as the driving force
behind numerous research initiatives. This is followed by various challenges in CBMIR.

In **Chapter 2**, various problem areas of Content Based Image Retrieval and Content Based Medical Image Retrieval according to the approach and solution technique used are studied, and discussed the characteristics of the approaches.

In **Chapter 3**, an image retrieval system based on various techniques for feature extraction and similarity measurement is developed. The experiment is performed on three different datasets in order to measure the accuracy and robustness of the system. It has been observed from the experimental study that FD and CD combination gives better result in terms of delay, precision and recall. Future work may be carried out in the field of image enhancement and there is a need for GUI based CBIR-MD for creating better user interface to interact and work efficiently with the system.

In **Chapter 4**, an algorithm based on a simple HVS model for image quality assessment is presented. CSF used in this model is not fixed; it has one user-defined parameter to control attenuation at high frequencies. Finally, image quality measure is computed as the average correlation coefficient between two input images modified by the average correlation coefficient between original image and error image. It helps to differentiate between random and signal dependant distortion, which have different impact on a human observer.

In **Chapter 5**, a content based image retrieval system for medical images based on various techniques for feature extraction and similarity measurement is presented. In addition to these techniques, a bipartite graph partitioning and integrated minimum cost matching technique is incorporated. The experiments are performed on three different datasets in order to measure the accuracy and robustness of the system. The experiments result also confirmed the efficiency of proposed system.

In **Chapter 6**, a content based image retrieval system using the merits of Local Tetra Pattern technique for medical images is presented. The
experiment is performed on Messidor dataset of 1200 retinal images and results confirm the efficiency of proposed medical image retrieval system. The results also highlight that the local tetra patterns provides superior performance when used with FD/CD rather than FD/ED. The SS-SVM applied on binary patterns of datasets images for classification of medical images which results in improved average accuracy 88% for retinal images dataset.

Finally, Chapter 7 summarizes the research. It also gives an outline of the broader impact of the thesis and provides the scope of future research. The thesis is concentrated on the Content based Image retrieval for Medical Databases. Content based medical image retrieval schemes presented in this thesis are promising still there is significant scope for future research. This research work improves the understanding of various techniques for feature extraction and similarity measurement which aids medical image retrieval and advances the state-of the art through its contributions. Its investigation has revealed areas in medical field where much work remains to be done. The incorporation of various techniques presented in this research work raises a number of challenges for further research such as validate the practicality of proposed model in real environments:

- Using a realistic medical environment.
- Consideration of digital medical images with different priorities.
- Incorporating more sophisticated medical image retrieval techniques.
- Developing a retrieval system using Local Tetra Pattern technique considering the diagonal pixels for derivative calculations.
LIST OF PUBLICATIONS


