

Content-Based Computer Tomography Image Retrieval on a Whole-Body Anatomical Reference Set: Methods and Preliminary Results

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Abstract. This paper describes a CBIR system presenting two key points: a generic CT data, as well as a novel algorithm for combining visual features. The descriptors express grey levels, texture and shape of the images. A normalization method is proposed in order to improve the quality of indexing and retrieval. Our selected features and our combination method are effective for retrieving images from a whole-body reference set.

1 Introduction

The number of numerical images produced increases every day, particularly in medical imaging, which has benefited from recent technological improvements. Strong needs for storing, indexing and retrieving these huge amounts of data have emerged at the same time.

A Content-Based Image Retrieval (CBIR) system aims to retrieve the most similar images to a query from a database. In CBIR systems, the query is an image, as textual queries cannot describe precisely all the visual characteristics of an image. The main idea is to extract some "features" from the images, which will be compared for retrieval.

Figure 1 presents the general framework of CBIR systems, which processes in two phases. The first one extracts some visual descriptors from the images in the database and stores them. The second one is the real-time retrieval phase. The user inputs a query image, from which descriptors are extracted and compared to the ones in the features database. The system finally retrieves most similar images.

In the field of medical practice, CBIR is often associated to Computer Aided Diagnosis (CAD). By integrating computer assistance in the diagnosis process, the goal is not to get rid of medical expertise but to improve its efficiency and accuracy. Current trend is to design diagnosis-driven (and then very specific) systems, which makes their evaluation a significant problem.

Our aim is to create a Content-Based Radiology Image Retrieval (CBRIR) system which retrieves a close positioning of a medical image in the body (in order to know if the image content is the brain, the liver...). Image positioning is the first step of radiology diagnosis. Most systems work on very specific data, as mammographies [1] or inter-vertebrae disks [2]. This was defined in [3] as the "use context gap". The system we propose covers the full human body. The remainder of this paper is divided into

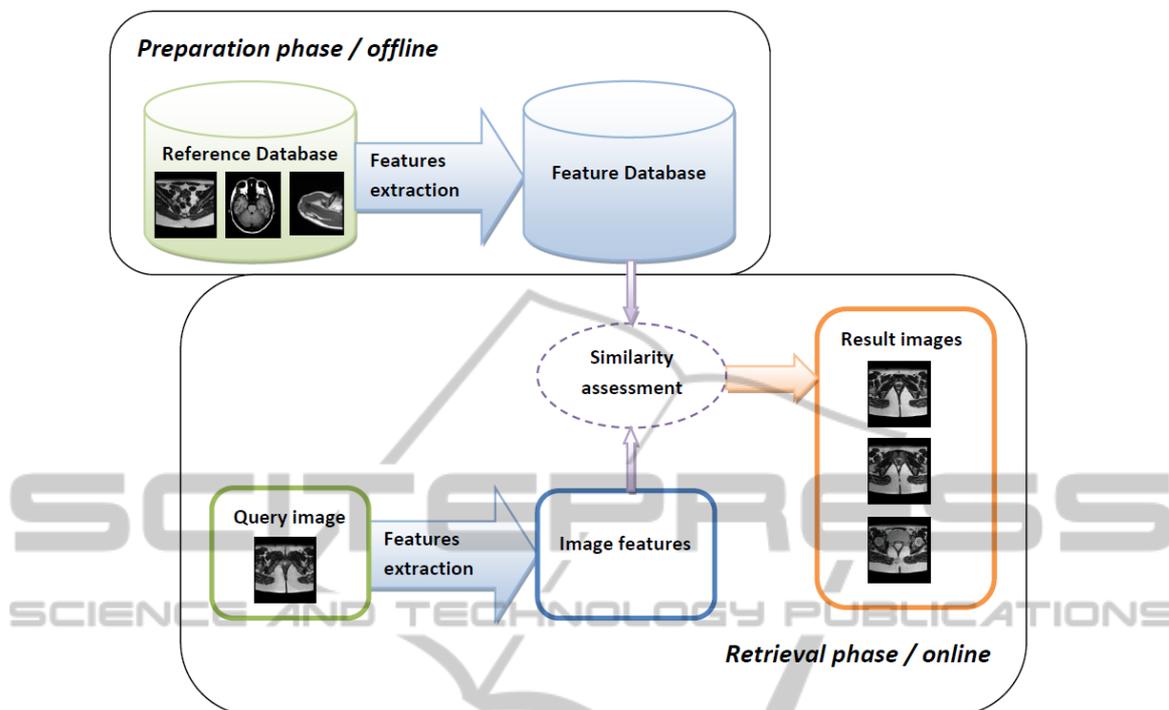


Fig. 1. General framework CBIR systems.

tree sections. In Section 2, we describe the characteristics of our system, our data and method, including our features combination algorithm. In Section 3, we present results, and in Section 4, we state the conclusion of this work.

2 Material and Methods

2.1 Our CBIR System Characteristics

In a previous paper [4], we presented an overview of the key points of CBIR systems. Table 1 shows the characteristics of the system we propose.

Table 1. Characteristics of proposed CBIR system.

Image Modality	Computer Tomography (CT)
Data content	General (from head to pelvis)
Application	CT slice positioning in the body
Query	A single image
Visual features	Descriptors used for expressing the image content (described Section 2.4).
Distance measure	In order to express the similarity / dissimilarity between two images. (described afterwards)

2.2 Our Image Database

We work on an anatomical atlas, proposed by the company IMAIOS (e-Anatomy). The anatomical structures are localized and captionned in each image of a huge set of over 20,000 CT images. Our reference set is made of 380 CT images with a 3 mm section thickness, from a single patient. It goes from the brain to the pelvis. Thus, even if the images are in 2D dimension, 3D information can be extracted. The originality of our approach is due to this volumic information and the cover of a large range instead of focusing on a single anatomical structure. Our test database is a set of 10 CT images coming from different patients than the one used as reference. The aim of our system being to work in a real medical context, the test images were not chosen ideal: some elements as table or pipes, external to the patient, can be seen on them, the body is not always centered. A test image is shown on Fig. 2.



Fig. 2. One of our test images: patient badly positioned, and visible examination table.

2.3 Normalization

In order to work on the significant part of the CT images, we implemented a normalization method. First of all, the original image is convolved by a mask in order to get the contours. Then a threshold is applied, before getting rid of unwanted elements on the image (for example external to the patient body: table, pipes...). The Region Of Interest (ROI) containing the patient is automatically defined, then is being scaled and positioned in a 256x256 image. The grey levels are finally normalized. Figure 3 presents the normalization process on an image of our test dataset.

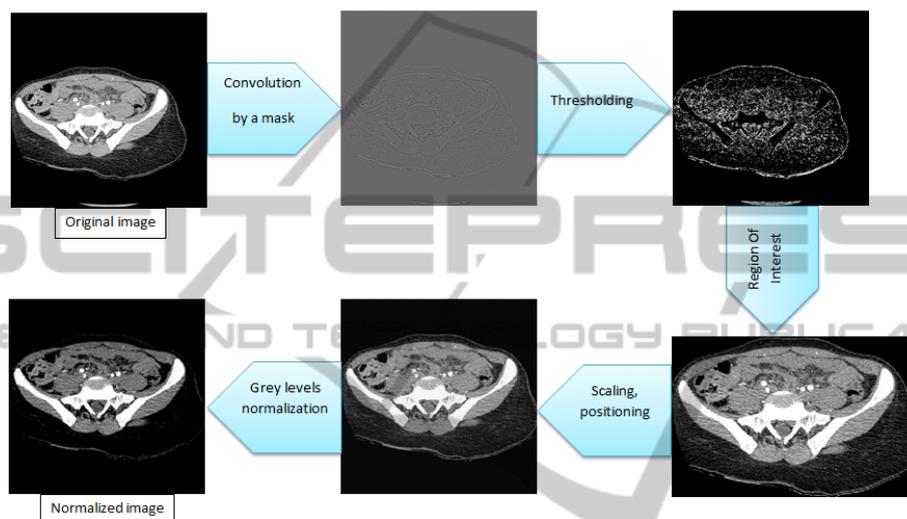


Fig. 3. Normalization process.

2.4 Features and Distance Measures

Visual features, also named descriptors, express the image content. A presentation of the different types of features used in recent CBRIR systems and their classification were presented in our previous paper [4], reviews as [5,6] may be read for a more global view of existing CBIR systems. We will list here the one we currently tested. In this work, we use only general descriptors, that can be extracted from any image. The features describe either color, texture or shape. We compute them over the whole image, or on each block obtained by dividing the image in small patches of equal size.

Color Features: Histograms represent the grey level distribution of an image. We used it directly as a feature, as in [7–9], but we also computed some statistical descriptors ([10]) such its mean, standard deviation and skewness (asymmetry). Different functions can be used to estimate the divergence between two histograms, influencing the quality of the results.

Texture Features: We tested 6 of the 14 Haralick's descriptors: contrast, dissimilarity, second angular moment, mean, homogeneity, entropy, maximal probability and standard deviation. These are statistical values extracted from the Grey-Level Co-occurrence

Matrix (GLCM) of an image, which represents the spatial relationship of a given (distance, angle) couple, between pixel values. This method is described by Haralick in [11] and used in numerous CBIR systems, such as [10, 12, 13]. A GLCM in 4 directions is computed on each block after dividing the image in numerous little windows. We tested different distances and window sizes.

Shape Features: We tested five shape features: Fourier Descriptors, Procrustes analysis and three simple geometric descriptors. After a Fourier transformation, we take as features the first low frequency normalized coefficients, which are named the Fourier Descriptors [14]. Many simple geometric measures can be computer over the shape (see [14, 15]). We chose three of them: circularity (distance from the object shape to an ideal shape, a circle), eccentricity (principal axis ratio), and variance. Procrustes analysis ([14, 16]) determines the best linear transformation between two shapes (translation, rotation, scale) then returns a distance measure used as a descriptor.

Direct Comparison: Direct comparison criteria cannot be called visual features, but they can be considered as distance measure functions between the whole images considered as probability distributions. We tested both linear correlation ([17]) and mutual information. For two images $I1$ and $I2$:

$$linear\ correlation = \frac{covariance(I1, I2)}{\sqrt{covariance(I1, I1) * covariance(I2, I2)}}$$

$$mutual\ information = \sum_{i,j} P(i, j) * \log_2 \frac{P(i, j)}{P_1(i, j) * P_2(i, j)}$$

with, for each pixel (i,j) , P the joint probability distribution function of $I1$ and $I2$, and P_1 and P_2 the marginal probability distribution functions of $I1$ and $I2$ respectively.

2.5 Proposed Combination Method

With the use of only one feature, results are not always stable, as illustrated by Fig. 4. In order to improve individual results, the informations from several features are combined. Often, each feature is given a weight and the results are computed accordingly to these weights. Weights can be determined either in an arbitrary way (all features are of equal importance, [18]) or by relevance feedback or with a learning algorithm [19].

We present a different method, which reduces computational time, based on successive refinements of the results. Its framework is shown on Fig. 5. We applied this algorithm on the three features retrieving the results of best quality on our dataset. The best tenth results given by the comparison of the first individual feature are returned. It determines a low and high limits of search in our reference dataset, *i.e.* in the body range. We then compute the second feature on the reference database in the images within these boundaries. Finally, the third feature is compared to the images in the range determined by the second feature in the reference database. This method allows the distance measurement between the test feature and a limited number of the reference dataset descriptors.

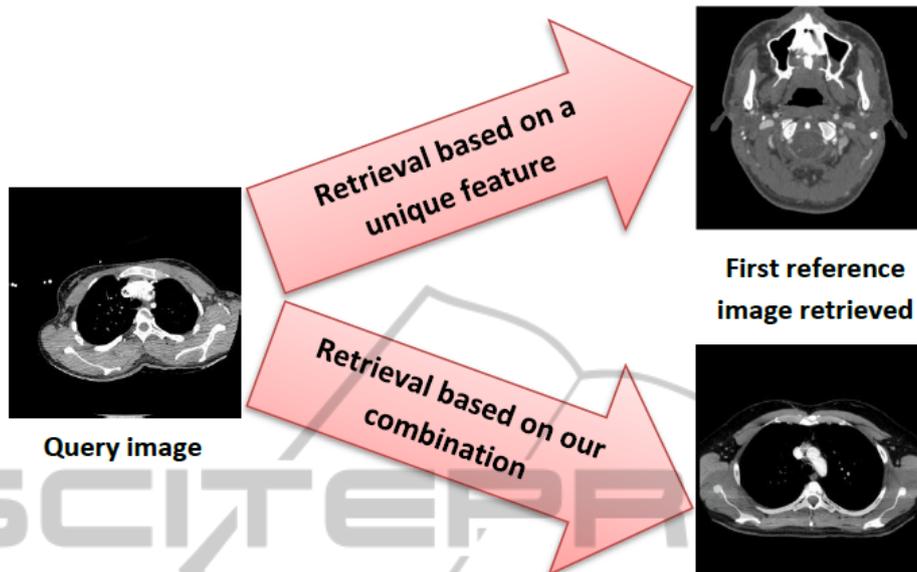


Fig. 4. Combination process.

3 Results and Discussion

We chose, in order to evaluate our method, two criteria. The first one is the graph Precision versus Recall. The second one is the distance in millimeters between the ideal image and the image retrieved. A radiologist determined for each test image the closest image in the reference database. Our results are presented in this section.

3.1 Distance

Given that each image in the reference database is 3 millimeters distant to its neighbours, we computed the distance between the top ten images retrieved and the ideal image. Then, cumulative distance was calculated for each test image and its ten first results, as well as the total cumulative distance for the whole dataset. These values will be used to make comparisons in our future work. We obtain 48mm as an average distance for the first image returned to each of the ten test images, which we estimate as a good start for our system.

Some results and their associated distances are presented in Figure 6. We can see that results are stable: for a query image, most retrieved images are very close between them. In shown results, the closest reference image is retrieved in second, fifth and third position from top to bottom query. In future work, we plan to improve these positions.

3.2 Precision vs. Recall

We decided to follow the idea proposed by [20]. We determined a pertinence criterion based on the distance defined above: a retrieved image is estimated pertinent when its

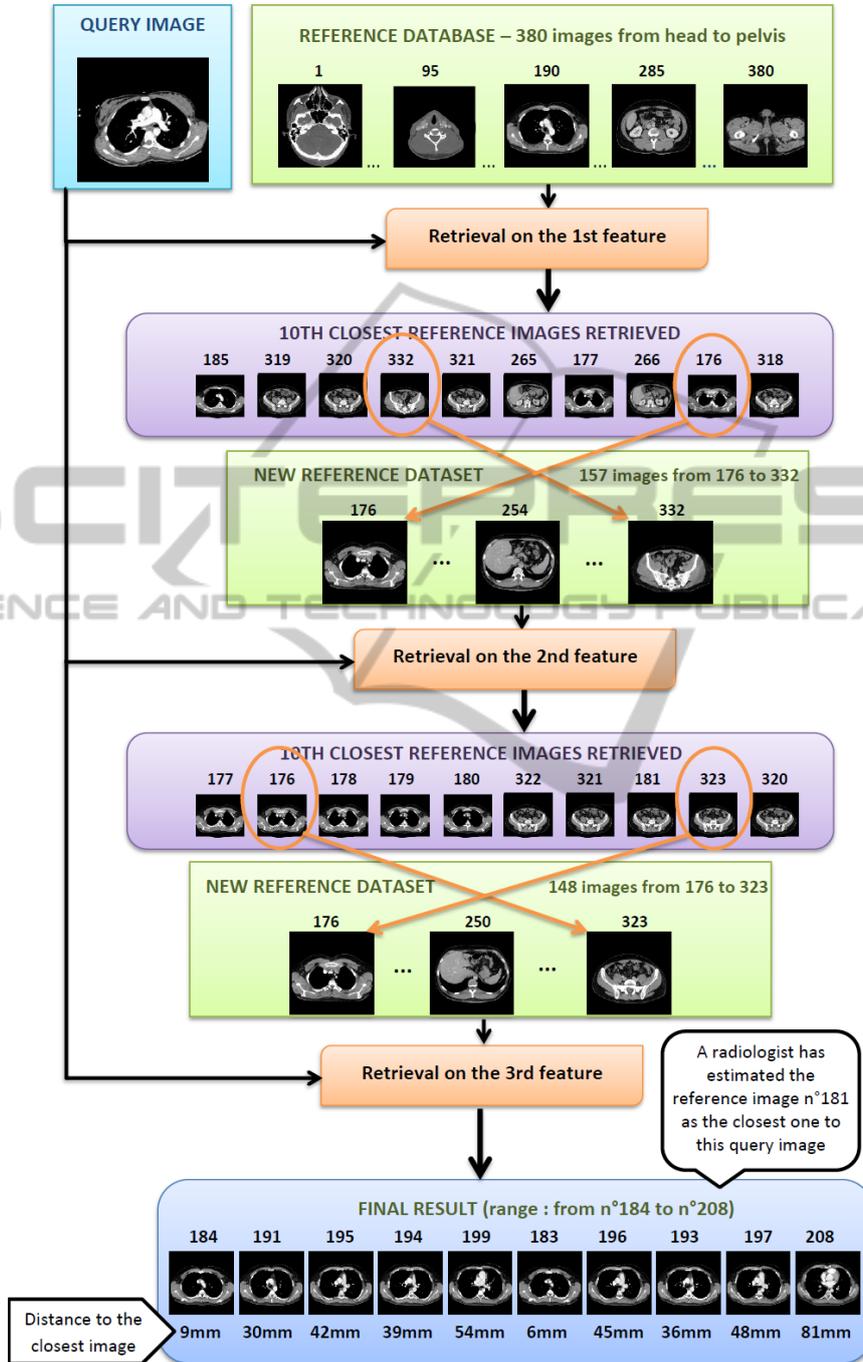


Fig. 5. Combination process.

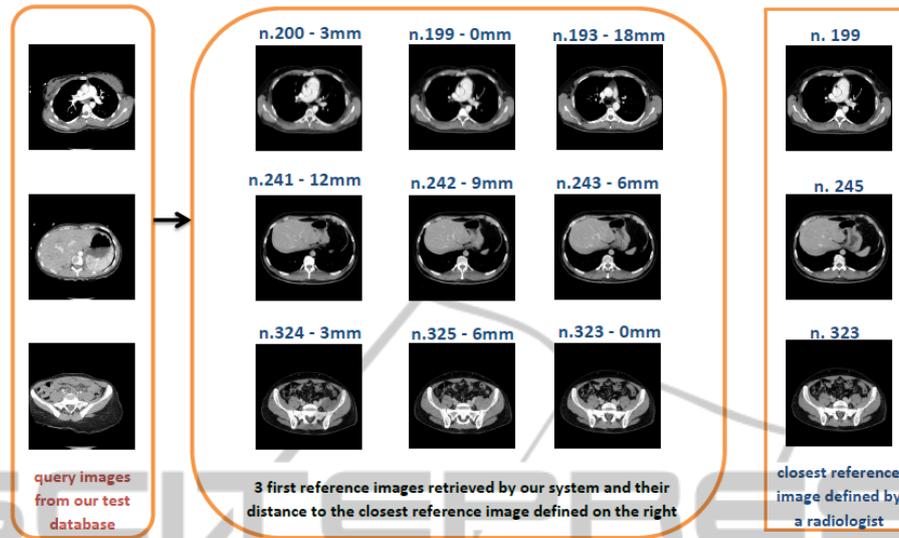


Fig. 6. Distance results - 10 first images retrieved to each query image.

distance to the closest reference image is less or equal to 30mm. A radiologist has estimated this value as a good estimator for our current positioning system. For each pertinent image retrieved, we obtain a recall value, defined as

$$recall = \frac{\text{number of pertinent results retrieved until here}}{\text{total number of pertinent results in the database}}$$

as well as an associated value of

$$precision = \frac{\text{number of pertinent results retrieved until here}}{\text{number of results retrieved until here}}$$

The precision can be seen as the system ability to retrieve, in the first results, mostly pertinent images. The recall, as the capacity of the system to retrieve all pertinent results of the database.

The mean of the precision values obtained for each recall value is computed for all the test images and presented Fig 7. The curves show that our combination gives an overall higher precision than individual features. However, these individual characteristics perform a better precision for some recall values (1/21, 2/21, 3/21 and 8/21). We intend to work on this point in future work. An ideal combination would not lose precision in comparison to individual visual features.

4 Conclusions

This paper presents a CBIR system that incorporates a new features combination method and is dedicated to work on generic CT images. The advantages of our three-steps combination are its multiscale approach, which permits fast retrieval, and its modularity.

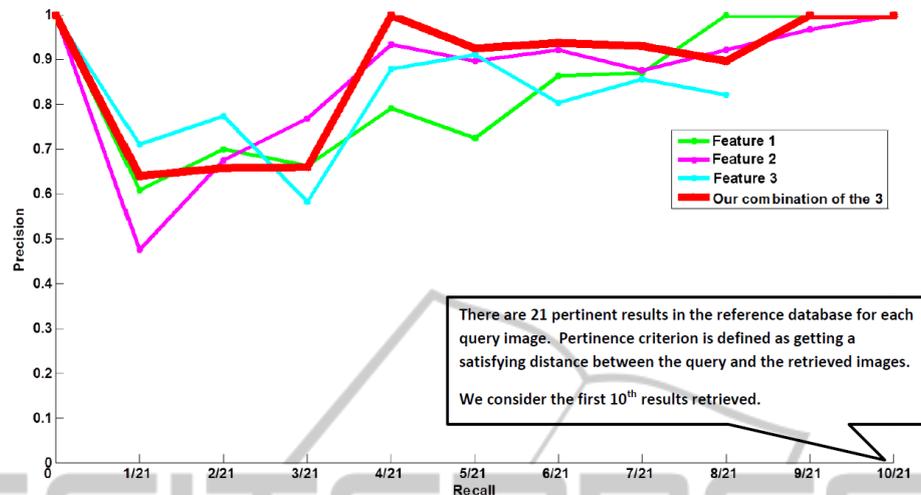


Fig. 7. Mean of Precision values for each Recall value.

This last characteristic will make our next improvements easy to integrate: the number of steps can be set higher, and features can be permuted or changed. The first results seem promising. Future work will be to confirm the interest of our method on a larger test dataset, and compare it to other combination processes.

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