AUTOMATED CONTENT BASED IMAGE RETRIEVAL TECHNOLOGY (CBIR): BASIC PRINCIPLES AND ITS APPLICATION ON DERMOSCOPIC IMAGES OF PIGMENTED SKIN LESIONS

Alfonso Baldi[1] and Stefano Bizzi[2]

[1]Department of Environmental and Life Science, Second University of Naples, Naples, Italy;

[2]ACS, Advanced Computer Systems, Rome, Italy.

*<u>*Corresponding author:*</u>
Fax: +390815569693;
email:
alfonsobaldi@tiscali.it

Abstract

Dermoscopy (dermatoscopy, epiluminescence microscopy) is a non-invasive diagnostic technique for the *in vivo* observation of pigmented skin lesions (PSLs). This diagnostic tool permits the recognition of morphological structures not visible to the naked eye, thereby providing a new dimension to the analysis of the clinical morphologic features of PSLs. Due to the difficulty and variability of human interpretation, computerized analysis of dermoscopy images has become an important area of research and Numerous systems designed to provide computer-aided analysis of digital images have recently been reported in literature. Content-based image retrieval systems (CBIR) technology exploits the visual content in image data. It proposes to benefit the management of increasingly large biomedical image collections as well as to aid clinical medicine, research and education. The goal of this article is to describe the application of CBIR systems for dermoscopic images, describing in detail the FIDE model created in our laboratory. FIDE's function is to document the image analysis side of the diagnostic process, focusing on accompanying and aiding it, and on providing efficient digital atlas navigation by providing precision (cases most similar to the one under analysis) and clarifying context (similar cases in different categories). The FIDE system is effective in retrieving PSL images with known pathology visually similar to the image under evaluation, giving a valuable and intuitive aid to the clinician in the decision making process. FIDE represents, indeed, the first CBIR system successfully applied to dermoscopic images. The real impact of this system in clinical practice will be revealed only by its application in a wide clinical setting.

Key words: content-bases image retrieval, dermoscopy, melanoma

Content based image retrieval systems (CBIR)

There has always been a question as to whether the works of Leonardo da Vinci are illustrations with text describing them, or text with illustrative figures. Of course, it is the combination of text and images which optimizes our powers of perception and conceptualization so we can understand the message being communicated, and indeed, this concept has been clearly defined by the divine poet Dante Alighieri (Figure 1).

Figure 1: Dante Alighieri's lyric underscoring the concept that the combination of text and images optimizes our powers of perception and conceptualization

Engineering works of the Renaissance exemplify the coexistence of these two methods of communication. Leonardo’s success, already recognized during his lifetime, was and continues to be intimately tied to his ability to communicate even the most complex concepts in an immediately clear and satisfying manner. Many of Leonardo’s works can be understood without mastering the arcane language of the text, which is abstruse today, even for Italians.

And now back to the present where we have machines capable of handling unlimited databases containing both information and images, and which require electronic tools or search engines to be of reliable and rational use .

Most common of these, the “Full Text” search engines, takes us like blind men led by a seeing eye dog, close to the information that interest us and then leaves us to choose between a number of possibilities. Search engines using the concept based image indexing, do not understand natural (human) language but take advantage of the fact that similar arguments are presented by authors using words or sequences of similar terms. The selection of documents that contain the words of our query (words conceptually associated with the theme of our research), bring up documents likely to contain the topic of interest. This does not always work out but it is, nevertheless, "better than nothing" and really useful. Google docet (Google teaches!)

Although this may satisfy our desire to search, and use all humanly accessible knowledge found amongst the infinite textual documents available on the web, there are two important concerns:

1) Textual Search engines perpetuate the biblical punishment of Tower of Babel’s “confusion of tongues” and

2) Textual Search engines, or the processes of content-based image retrieval, do not allow for the selective retrieval of the human knowledge contained in contents of the images as defined by similarity to the subject in an image data. This is exactly what "human visual

memory" does when we see an image (face, object, painting, scene of a movie, etc.) This is the image of interest to us at the moment, the "query image".

The first concern suggests the need of a common language. The second, the need for visual memory. The goal is to form large databases of these digital images with a visual memory capable of retrieving the images through the matching of some common elements, so that the image becomes an Image Query, matching the common elements in a particular data image and all those contained in our memory-archive, and then selecting a match or the most similar.

Specifically, in this case, "similar" means exactly what we mean when we use it in the spoken language, which can mean everything or nothing. That is to say, typically the concept of “similar” is structured differently depending on the nature of the image and of the interest of the specific observer. Mushroom searchers and sign cutters may look at the same forest, but they do so in different ways and they use a different criterion of similarity.

Search engines that successfully select, from an almost infinite database, those images most similar to the subject provided by the user, (the query image), do exist, and are generally known as Content Based Image Retrieval engines (CBIR) (Deserno et al., 2008; Gao et al., 2011).

The field of CBIR engines is relatively new, but it is growing rapidly and is making the large digital image databases accessible and usable. This ability to profitably benefit from this vast trove of “photographic" documentation, is promoting the establishment of vast diagnostic image collections that can be used to support a "differential" for a new diagnosis.

Since CBIR engines are still growing, this is the time for them to be creating image databases that are homogeneous in terms of the nature of the sensors, resolution, and observed phenomenon. The correlation between the physical parameters measured by the sensor image acquisition diagnostics (temperature, color, transparency, textures, etc.) and the numerical value assigned to them in all the images of the archives, is of fundamental importance and an absolute prerequisite/ essential qualification for the functionality and reliability of the CBIR engine

How does a CBIR work?

A CBIR extracts or synthesizes the characteristic elements of the image as it relates to the concept of similarity between the images in the database wherein the selection process is realized by matching the content. In the case of diagnostic images, the goal is to instruct the engine to evaluate the similarity in terms of components and characteristics of the subject disease pathology. So, the engine to determine selections of similarity between images of skin lesions acquired through digital epiluminescence microscopy will be different from the engine to determine similarity in human embryo images acquired through a microscope.

Each of the engines will give weight, in terms of similarity, to the calculation of the value of similarity, in several aspects of the image. For example, in the image, you can give more or less weight to the color, texture, shape, or the presence of a certain typical pattern of a particular disease.

How is a CBIR designed and realized ?

Simply stated:

1. Establish the significant elements of the image, correlated to the similarity of the pathology, symptoms, etc.. of that specific database. (Color, shape, texture, pattern, etc.)

2. . Develop the algorithms for quantitative evaluation or an on / off switch, for each significant element inside the diagnostic image.

3. Develop a quantitative criterion for calculating the value of similarity between two images as a complex / summary evaluation of the differences between the values assigned (step 2) to the two images.

4. In response to a request for selection from the database in accordance with a new " image Query " :

• For each pair: (Image Query, database image) apply the criterion referred to in paragraph 3. assigning the value

• The database images are ordered according to the decreasing value of similarity with the query image and is served "hot" to the user. A list of interactive display functions support the user in comparing the new lesion to be interpreted (evaluated), with each image selected from the archive. A selected lesion will be presented in the screen, side by side with the new lesion, in terms of video color data, clinical data, and of discriminant space visualization features.

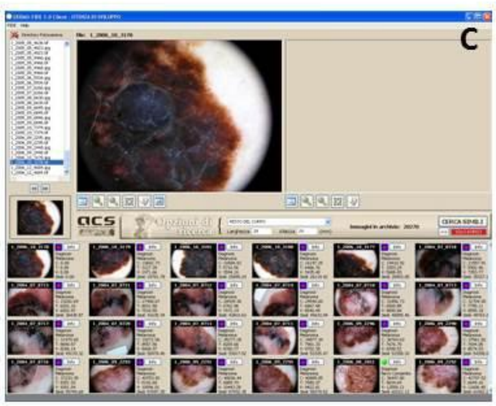
It is important to note that in the case of diagnostic images with the medical interpretations provided for the image in terms of pathology, in addition to retaining the digital image consisting of the numerical values of the physical parameters measured by the sensor acquisition of the image, the conceptual elaboration and interpretation that led to the medical diagnosis is also kept. This element constitutes the first step from which to identify "from diagnosis to the characteristics of the images" the discriminating parameters referred to in point 1 above, in the logic of learning from the data itself.

For the above reasons, it is crucial to have a vast database of diagnosed images in order to build and validate a CBIR engine able to sustain the quantity and quality necessary to support optimal diagnostic imaging.

Dermoscopic CBIR: the FIDE system

The process of describing picture content in textual terms takes on specific meaning in the case of image-based diagnostic activities e.g. in dermoscopic settings. Documenting the image interpretation process replicability for educational as well as legal issues, is essential to reduce diagnostic errors and improve effectiveness at different levels of medical organizations.

Several automatic image-based diagnosis systems have been developed by research groups involved in biomedical image analysis in past years (Dorileo et al., 2008; Rahman et al., 2006; Schmid-Saugeons et al., 2003; Wollina et al., 2007).



Among the other strategies, abstract features and machine learning methodologies or problem oriented model-based systems have been employed. Nevertheless, the principal problem with automated diagnostic analysis is, more than the false positives, the disproportionate cost of false negatives.

Our research group has recently developed an original CBIR system for dermoscopic images named FIDE (Baldi et al., 2009). This system is able to document the image analysis side of the diagnostic process, focusing on accompanying and aiding it and providing efficient digital atlas navigation with the aim of providing both precision (cases most similar to the one under analysis) and clarifying context (similar cases in different categories).

Figure 2: A) An exemplificative outcome of the search for similar pigmented skin lesions, using as query a dermoscopic image of a benign nevus; B) An exemplificative outcome of the search for similar pigmented skin lesions, using as query a dermoscopic image of an acral nevus; C) An exemplificative outcome of the search for similar pigmented skin lesions, using as query a dermoscopic image of a melanoma

We refer to the original work for the description of the apparatus developed for the acquisition of high quality dermoscopic images, for the clinical characteristics of the collected images, and for the absolute image contents selected for the analysis, as well as for the mathematical approach used to define and compare them (Baldi et al., 2009). In figure 2, three different examples of the CBIR search engine system user interface developed for a large archive of skin lesion are depicted.

FIDE, similarly to other described CBIR

systems, can be used to retrieve and display cases that are objectively similar by image content to the one used as query, together with medical records for the analyst to consider in order to document and assist the interpretation and diagnosis procedures. Furthermore, the diagnostic procedure can be documented by logging the acquired images.

In the FIDE system, the statistical analysis performed in order to assess the similarity among image items is based on a hierarchical Bayesian model-based data analysis approach. The Red-Green-Blue signal level model p(D) is linked to a high-dimensional primitive descriptor level p(P) taking into account color as well as geometric information extracted from the data and in turn to a secondary, lower-dimensionality, independent synthetic descriptor level p(S) by conditional probabilistic links p(P|S), p(S|P). Inference is conducted in order to obtain the posterior density p(S|P) p(P|D) p(D). The obtained densities are compared with each other taking into account a bank of distance and divergence measures to carry out an association level search procedure. Category search is employed to limit search results discriminating among retrieval outcomes of different natures. Again, we refer to the original paper for the description of the different categories considered, as well as of the statistical tests used to confirm their validity (Baldi et al., 2009). Standard measures of retrieval performance are considered in the development and evaluation of the system performance. Clusters are defined by the available supervised diagnoses attached to each of the items. The centers of mass of each of the clusters can be calculated, as the relative distances of the different centers of mass provide a further measure of the quality of the ranking output by the retrieval system.

The FIDE system is effective in retrieving PSL images with known pathology visually similar to the image under evaluation giving a valuable and intuitive aid to the clinician in the decision making process. Indeed, we speculate that a system, able to retrieve and present cases with known pathology similar in appearance to the lesion under evaluation, may provide an intuitive and effective support to clinicians which logically can improve their diagnostic accuracy. Furthermore, this CBIR system can be useful as a training tool for medical students and inexpert practitioners, given its ability to browse large collections of PSL images using their visual attributes. The system allows the user to mark retrieved images as positive and negative relevance feedback. This very important feature will permit better evaluation of the performance of the proposed system and, consequently, further tune the weighting factor parameters in order to improve the relevance of the retrieved PSL images. Furthermore, the proposed system can be used to create appropriate CBIR Web Services that can be used remotely to perform query-by-example in various PSL image databases around the world and can be an excellent complement to text-based retrieval methods.

Conclusion

Dermoscopy has higher discrimination power than naked-eye examination to detect pathologic PSLs, if performed by trained physicians. Computer-assisted automated diagnosis of PSLs by means of CBIR systems is a promising research field. FIDE represents, indeed, the first CBIR system successfully applied to dermoscopic images. The real impact in clinical practice of this system will be revealed only by its application in a wide clinical setting. Finally, a similar search engine may realize possible usage in every sector of imaging diagnostic, or digital signals (NMR, Video, Radiography, Endoscopy, TAC, etc.), which could be supported by the extensive amount of information available in medical archives.

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