SOLO-MEDICINE IN OPTICAL BIOPSIES. A WAY TO PRACTICE TELEMEDICINE.

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Abstract. A way to practice Telemedicine is to access a data-base capable to assist you in medical procedures (diagnosis, treatment and prognosis), similarly to consult a book or to ask a college. In many countries the lack of specialists and training capabilities demand to practice solo-medicine, that in the case of surgery require robots capable to induce anesthesia or help in vision or handling instruments.
A relevant case is the diagnostic self-training requirements for optical biopsies (OBs) obtained with confocal laser endomicroscopy (CLE) or the assistance in the diagnosis of pathology slides. In both cases it is required a training set of digital images against which to compare the question case by means of *Image-queryformat*.
The present paper present a content-based image retrieval system (CBIR) based on the MPEG Query Format Standard in order to provide a set of similar pictures and the corresponding diagnosis to help on diagnosis or just to train the doctor. The paper defined the Image solo-medicine paradigm (ISMP) architecture merging medical image standards and MPEG and JPEG standards. It tested the solution with normal, and benign colon OBs with 90% congruency.
The ISMP is of particular interest viewed the proliferation of iPhone medical applications aiming to train doctors and support medical decisions.

Key words: Optical Biopsy. Query by image. ISO-15938-12, MPEG Query Format. MPQF. ISO 24800-3. JPSearch. JPEG Query Format. JPQF. Artificial Intelligence. Multimedia standard. Solo-medicine.

1 Introduction

Now a days the number of medical applications for iPhone proliferate[1], attracting the interest of relevant medical Journals such as the British Medical Journal[1] to build applications that help doctor to make their decisions and auto-train themselves. The time of training books, with periodical updates for new diagnosis or treatments,

[1] http://catai.net/blog//2010/06/anatomia-patologica-en-iphone/;
http://catai.net/blog//2010/06/en-india-el-hospital-mas-eficiente-del-mundo/

is arriving to an end; doctors will have on-line and on mobile phones that information, and will use mobile phones for a variety of medical applications[2][3][6].

We have been working in a diagnostic medical application based on images and on which "gold-standards" are still on the way [4] [11][12]. This is the so-called optical biopsy (OB)[5]. A non-intrusive optic diagnostic method, capable to analyze the tissue in surface and in deepness with one of the following techniques: laser, OCT, infrared, fluorescence, spectroscopy etc. This means, that it is not necessary to extract the tissue from the body. Tissue is accessed through the surface of the body through the skin or by endoscopy.

In OBs images are obtained in real time together with complementary information that allows evaluating the disease in vivo, but "gold-standards" are still lacking while in surgical pathology standards lay on the histology of the normal fixed tissue [7]. To provide training and self-confidence on OB diagnosis, two possibilities are open: (a) Tele-consult to a pathologist or (b) Train themselves with a non-supervised search for a "similar image" on the Net using multimedia query and image mining techniques [9][10] .

Standardization efforts to annotate, search and retrieve digital images are now a day taking place in many domains. Two of the more relevant initiatives are the MPEG Query Format (MPQF) [8][13] and the JPEG's JPSearch project [8][14]. While MPQF has already reached its last standardization level, the JPSearch (whose Part 3, named JPSearch Query Format or simply JPQF, is just a profile of MPQF) is still an ongoing work, and faces the difficult challenge to provide an interoperable architecture for images' metadata management. None faced medical images although as seen above diagnosis and support at distance is using smart phones.

There is an heterogeneous field of semantic description capabilities and almost every image retrieval engine provides a different interface or query format for searching for visual content. This situation contrast with the highly standardized semantics in medicine, and in this case in pathology description. Image retrieval, an interoperable navigation and search among a wide set of image repositories is up to now not practical. Urged on this situation, ISO/IEC SC29WG1 (more commonly known as JPEG) initiated JPSearch (ISO/IEC 24800)[14] to develop relevant technologies to enable searching of an image archive. The JPSearch project aims on standardizing interfaces of an abstract image retrieval framework. This framework should help to decouple the in general tightly coupled systems and provide interoperability during image search among JPSearch aware image repositories.

The present paper showed the preliminary results on Internet image search and discovery system for diagnostic medical purpose. Results were based on a training-set of CLE-OB images annotated with specific CLE semantics and using the standardized multimedia query format for JPSearch ISO/IEC 24800 to build a standardized ISMP (Image solo-medicine paradigm) architecture.

2 Material and methods

The proposed system to allow users to navigate searching similar images considered to be golden standards (due to the pathology confirmation and availability of patholo-

gy image) in a pair image database integrated by OB-CLE images together with the histological counterpart.

Images used in the present paper were provided by one of the authors (OFR) or taken from data published in Internet. All were JPEG images.

2.1 ISMP (Image solo medicine paradigm) architecture

The ISMP system provided tools to annotate an unknown OB-CLE image with keywords and image structural information for content based image retrieval (CBIR). Fig 1 summarizes the overall architecture.

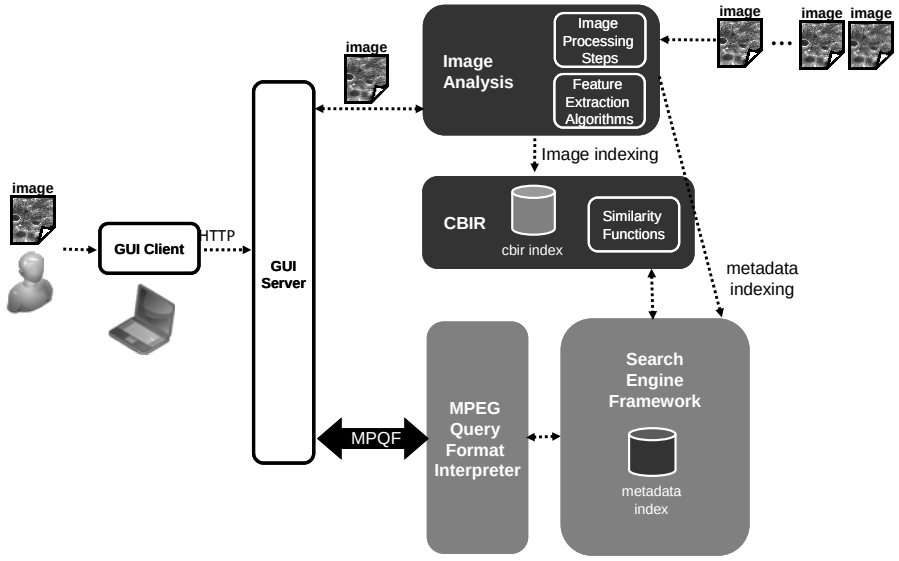

Fig 1. Overall architecture of Image Solo-medicine Paradigm(ISMP).

Image Solo-Medicine Paradigm (ISMP) architecture was integrated by four main modules:

1) Image processing: Offline extraction of medium-level and high-level metadata from the images in the database, and also to the on-the-fly extraction of the same metadata from an example image submitted by a user as a query. We used the ImageJ [15] Java library to implement an *adhoc* algorithm.
2) CBIR index construction: We generated an index for query-by-example search by means of selection of a feature vector and a similarity function.
3) Search Engine Framework: We built a query processor capable of solving text-based queries, CBIR queries and combinations of both.
4) MPEG Query Format Interpreter: In order to effectively ensure interoperability with potential third-party applications we built a standard interface based on ISO/IEC 15938-12:2008 (MPEG Query Format, MPQF).

2.2 ISMP Content Based Image Retrieval (CBIR).

The system was built to combine conventional search criteria (keywords, metadata ranges) with the direct usage of an example image (query-by-example paradigm) to retrieve similar images either OBs or pathology images.

For that purpose we built an automatic medium-level and high-level metadata extractor from images. It consisted on a *feature vector* and a discriminating and efficient *similarity function*, as can be seen in the results section. Similarity functions tested were: *euclidian distance*, the *manhattan distance* and the *quadratic-form distance*.

We implemented adhoc algorithms for feature extraction and similarity calculation with Java and the ImageJ Java library.

In the present paper images were presented to the web application to be search in a local data-base, although the application aimed Internet-retrieval.

2.3 ISMP Standard interface.

To assure system interoperability, we selected the ISO/IEC 15938-12 (MPEG Query Format or MPQF) and the ISO/IEC 24800 (JPSearch).

2.3.1 ISO 15938-12:2008. MPEG Query Format (MPQF)

The ISMP retrieval system contained an MPQF interpreter; an XML-based query language to define query-formats and to reply clients & servers in a distributed multimedia environment.

MPQF instances[2] (request & response) were integrated by: the *MpegQuery* element (root element), beneath that the *Query* element or the *Management* element. The *Query* element included the *Input* or the *Output* elements, which content were the Input (IQF) and Output Query Format (OQF).

2.3.2 ISO/IEC 24800 (JPSearch)

Searching of the ISMP system was based on image metadata according the JPSearch Part 2[3]. The model allowed multiple metadata formats and determined how can be queried using the MPQF.

3 Results

3.1. ISMP Training set.

It is composed by 25 OB-CLE images obtained with a PENTAX CLE with their resulting histological images (50 images in total).

[2] XML-documents followed the JPSearch Part 2 Core Metadata XML Schema

[3] Metadata model for the JPSearch framework

3.1.1. **ISMP preprocessing** was done in two steps: 1-Normalization (to minimize light in homogeneities caused by laser light source) that included several image processing steps (enhanced contrast, equalization, etc.). 2- Grey level reduction using *pixel value range reduction* and *region merging* algorithms as seen in Fig 2.

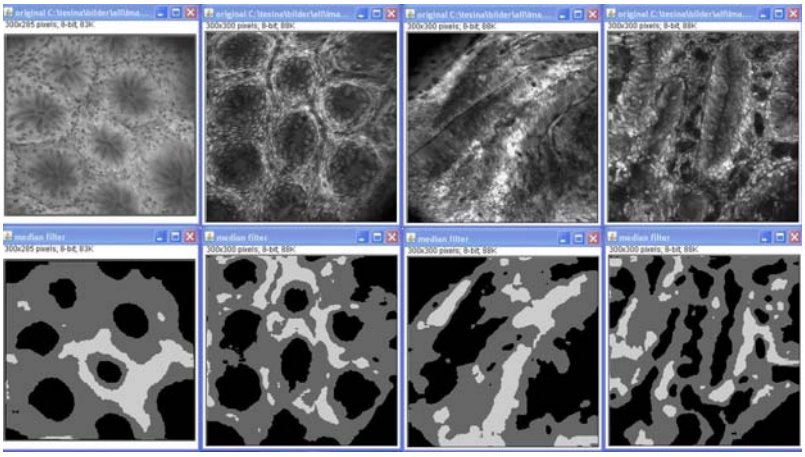

Fig 2. ISMP pre-processing of original images (top). Results in the bottom line.

3.1.2. **ISMP feature extraction** was done in two steps:

1.-The *Local Binary Pattern* (*LBP*) [16] operator (A gray-scale invariant texture measure derived from a general definition of texture in a local neighborhood). The process included (a) Integration: On each pixel, we calculated an array of bits of 0 and 1 comparing the original pixel value and its neighbors in a certain radius. (b) Decision maker: The array values are summed up. The higher *lbpSum* for a pixel indicated more likely to be the center of one of the big black areas (Figure 2).

2.- The *modified density-based DBSCAN* algorithm, highlighted the various crypts and their boundaries.

With the *lbpSum* value for every pixel, we apply a clustering algorithm to cluster to a certain crypt. In the clustering process **we used** a *modified density-based DBSCAN* algorithm originally proposed in [17]. See Fig 3.

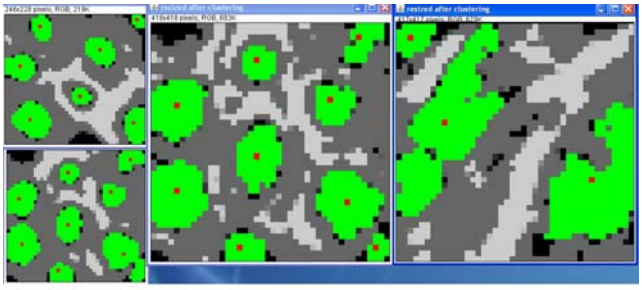

Fig 3. Clustering for gland identification. Normal (left) and hiperplastic glands (right).

3.1.3.- **ISMP feature measurement**: The results of this process allow us to extract and measure certain features such as the *silhouette coefficient*, the *crypt compactness*, the *crypt roundness* or the *inter-crypt distance*.

3.1.4 ISMP-indexing and ISMP-retrieval in two steps

3.1.4.1. We defined a **feature vector** and normalized it applying *linear scaling unit range normalization*.

3.1.4.2. We retrieved similar images to a given one, using the **similarity function**.

The selected function operated over the vector of selected features, whose composition determines which is the nature of the similarity being considered (similarity is relative in a multidimensional space).

The test set demonstrated that the *manhattan* and the *euclidian distance*, in combination with the linear *scaling unit range normalization*, provide better performance.

3.1.5 ISMP Data-base query

MPQF queries were evaluated against one or more multimedia databases which were unordered set of Multimedia Contents-MC (combination of multimedia data and its associated metadata).

3.1.5.1. Data-base: It was a dual database model (Figure 4) by content and by metadata. The MPQF operated over sequences called *evaluationitems*.

3.1.5.2 Condition Tree: It was dual condition tree since it (a) Combined filtering elements (conditions) from the BooleanExpressionType and (b) Interconnected them with Boolean operators (AND, OR, NOT and XOR).

The (image retrieve) IR-like condition used *QueryByExample* query type and included the Base64 encoding of the binary contents of a JPEG image.

The (data retrieve) DR-like condition specified, in the present case, that the metadata field *FileSize* must be less than 1000 bytes.

Each condition acted over a sequence of *evaluationitems* and, for each one, returned a value. For IR-like conditions, returned any value in the range of [0..1]. For DR-like conditions returned 1 or 0 (true /false).

A threshold value within a condition was used to indicate the minimum value the score to be processed in the training set.

3.1.6. ISMP Image retrieval

The ISMP retrieval system over the web interface present de problem image for query and retrieve a list of similar images (as many as possible) from the data base.

3.2 Test set

The web user interface used both 1) the query-by-image in combination with 2) classic XML metadata-based criteria.

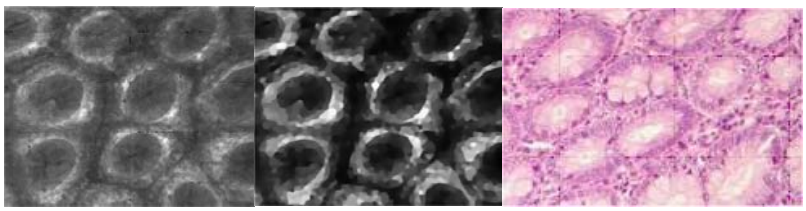

Fig. 4. ISMP retrieval in the Test set. Original OB image (left), preprocessing (middle) and retrieved image (right), in this case a histological image.

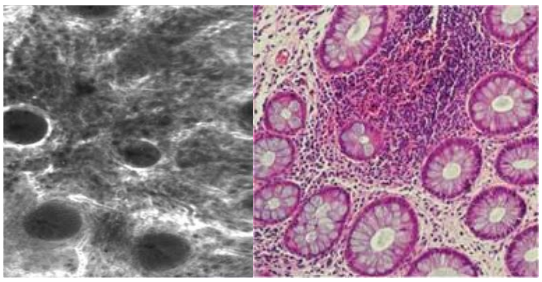

Fig. 5. ISMP retrieval in the Test set . Original OB image (left) and retrieved image (right) only histological images were retrieved.

The rate of adequate image retrieval from normal, benign and hyperplasic images using the threshold values indicated in the section 3.1.5.2 was 90%.

4 Discussion

The use of solo-medicine [3] will be a common practice in a near future, and therefore professional will require support by any media, including mobile phone. Two are the characteristics of this support: 1) is going to be on line (books will be soon obsolete) and 2) it will be required during patient interventions, therefore the possibility to get access to mobile phones is of paramount importance. The latter is even more relevant considering that the majority of this solo-medicine will be carried out in remote, isolated or developing countries where satellite mobile phones will be, probably, the only available technology.

The solution brought in this paper merge the standardization process of mass-used multimedia standards with the medical image standardization process, and built a ISMP (Image solo medicine paradigm) architecture, that in the present paper was applied to colon OBs (Optical Biopsies).

One of the main functionalities of the ISMP system architecture is the ability to combine conventional search criteria (keywords, metadata ranges) with the direct usage of an example image (query-by-example paradigm) to retrieve similar precedent cases. In the data retrieve DR-like conditions, the MPQF standard acts as a conventional Boolean-based filtering language, while with respect to (Information retrieve) IR-like conditions MPQF acts preserving scores as a fuzzy-logic system. The standard specifies the behavior of the provided Boolean operators in presence of non-Boolean values.

The result showed that automatic feature- extraction by image analysis on Black & White images coming from the CLE, as well as color images from surgical specimens, reached the 90% congruency. Thus indicating that the image-query solution proposed in the ISMP architecture is an adequate one to give professional support in medicine at least in the normal and benign cases. Nevertheless we have to test the borderline and malignant ones to detect the sensitivity and specificity of the proposed solution.

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