Optical biopsy data base content retrieval with a smartphone

Tous R., Delgado J, Ferrer-Roca O.

***Abstract*— An optical biopsy (OB) is an optic diagnostic method capable to analyze the tissue in surface and in deepness without the need to extract it from the body. When obtained through confocal laser endomicroscopy (OB-CLE), the optical biopsies are taken by endoscopists, not trained in microscopic morphology which is the domain of the surgical pathology. To gain diagnostic confidence, the endoscopists could consult the images to a pathologist or could query an OB database. This paper presents a case-based computer-aided diagnosis system that assists medical personnel in the interpretation of OB-CLE images. The system design enables operation from a smartphone. Users are able to retrieve information about precedent diagnostics by providing an example OB image for content based image retrieval (CBIR), by using keywords, or by filtering different fields for structured retrieval. To effectively ensure interoperability with potential third-party applications the system provides a standard interface based on ISO/IEC 15938-12:2008 (MPEG Query Format) and ISO/IEC 24800 (JPEGSearch).**

***Index Terms*— Medical image search, CBIR, multimedia, images, metadata, search and retrieval, standard, MPEG, JPEG, MPQF, JPSearch, query format.**

***Abstract*— Una biopsia óptica (OB) es un método de diagnóstico óptico capaz de analizar el tejido en superficie y profundidad, sin la necesidad de extraerlo del cuerpo. Cuando se obtiene a través de un endo-microscopio láser confocal (OB-CLE), la biopsia óptica es realizada por endoscopistas, no entrenados en morfología microscópica el cual es campo de la patología quirúrgica. Para ganar confianza en el diagnóstico, el endoscopista podría consultar las imágenes a un patólogo o podría consultar en una base de datos OB. Este artículo expone un caso basado en un sistema de diagnóstico asistido por ordenador que ayuda al personal médico en la interpretación de las imágenes OB-CLE. El sistema permite acceder mediante un teléfono móvil inteligente. Los usuarios son capaces de recuperar información sobre diagnósticos precedentes proporcionando un ejemplo de imagen OB por el contenido basado en recuperación de imagen (CBIR), usando palabras clave, o filtrando diferentes campos para la recuperación estructural. Para asegurar la interoperabilidad en aplicaciones potenciales de terceros con eficacia el sistema proporciona un interfaz estándar basado en la norma ISO/IEC 15938-12:2008 (MPEG Query Format) y la norma ISO/IEC 24800 (JPEGSearch).**

***Palabras Clave*— Medical image search, CBIR, multimedia, images, metadata, search and retrieval, standard, MPEG, JPEG, MPQF, JPSearch, query format.**

I. INTRODUCTION

COMPUTER-AIDED detection and diagnosis (CAD) are procedures in medicine that assist medical personnel in the interpretation of medical images. One of the possible applications of CAD, is the provision of a searchable database where physicians are able to retrieve information about precedent diagnostics. This paper addresses the question of how to build a case-based computer-aided diagnosis system that assists physicians and other medical personnel in the interpretation of optical biopsies obtained through confocal laser endomicroscopy. An optical biopsy (OB) [1] is a non-intrusive optic diagnostic method, capable to analyze the tissue in surface and in deepness using laser, OCT, infrared, fluorescence, spectroscopy or other methods. This means, that it is not necessary to extract the tissue from the body. This paper focuses on OB obtained through confocal laser endomicroscopy (OB-CLE). OB-CLE is a confocal microscopy that obtains histological images closer to the field and training of pathologists than endoscopists. It is therefore reasonable the lack of confidence on their interpretation. To solve the problem without the need of teleconsultation with a pathologist, the endoscopists could consult a medical images search system such as the one described in this paper. The system enables retrieving information about precedent diagnostics by providing an example OB image for content based image retrieval (CBIR), by using keywords, or by filtering different fields for structured retrieval. Besides, the system has been designed to allow operation from a modern smartphone such as iPhone®. Nowadays the number of medical applications for iPhone® proliferate [2], attracting the interest of relevant medical Journals such as the British Medical Journal [3] 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, 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 [4][5][6].

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RTI. At the Universitat Politecnica de Catalunya Universidad Politécnica Catalunya –Email: rtous@ac.upc.edu. Web: http://personals.ac.upc.edu/rtous/ Address: Office C6-123 Campus Nord Departament d'Arquitectura de Computadors. Universitat Politecnica de Catalunya. Jordi Girona street, 1-3. 08034 Barcelona (SPAIN). Phone: +34-934054044. Fax: +34-934017055

JD is the with the Universitat Politecnica de Catalunya, Jordi Girona, 1-3 08034 Barcelona (Spain); e-mail: jaime.delgado@ac.upc.edu .

OFR. Olga Ferrer-Roca, is the Chair woman of the UNESCO Chair of Telemedicine at the University of La Laguna. Faculty of Medicine. Canary Islands. Spain. catai@teide.net . phone: +34-922-319321. Fax: +34-922-641855.

II. Optical Biopsy Retrieval System

A. System's architecture overview

We have designed an optical biopsy retrieval system which will allow endoscopists navigating and searching over an OB-CLE image database. Endoscopists will be able to refine their search results by selecting a representative image (the example) and using it to submit a new query based on the selected example. This way an endoscopist can gain diagnostic confidence for situations in which the teleconsultation with a pathologist is not feasible. The overall functionality of the system is divided in the following independent tasks (see Figure 1):

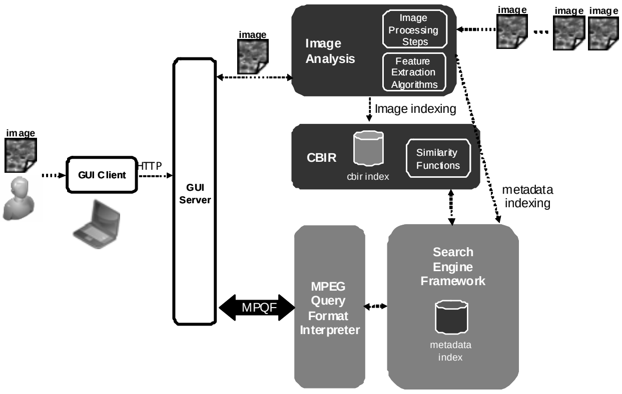

Figure 1. Overall architecture of the Optical Biopsy Retrieval System

- Module I: Image processing and analysis: Applied to the 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.
- Module II: CBIR index construction: Generation of an index for query-by-example search. Implies the design of feature vectors and also the selection of a similarity function.
- Module III: MPEG Query Format Interpreter: In order to effectively ensure interoperability with potential third-party applications. The system provides a standard interface based on ISO/IEC 15938-12:2008 (MPEG Query Format, MPQF).
- Module IV: Search Engine Framework: General query processor capable of solving text-based queries, CBIR queries and also combinations of both.

B. Image processing and analysis. Feature extraction

Image preprocessing is 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 Figure 2.

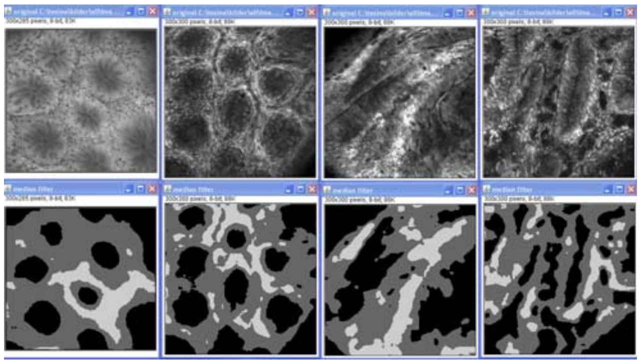

Figure 2. Preprocessing of original images (top). Results in the bottom line

Feature extraction was done in two steps:

1) The Local Binary Pattern (LBP) [8] operator (A gray-scale invariant texture measure derived from a general definition of texture in a local neighbor-hood). 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 [9]. See Figure 3.

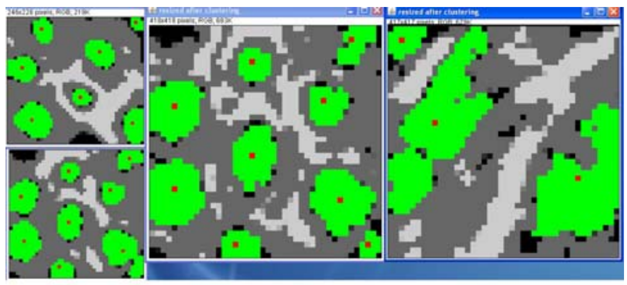

Figure 3. Clustering for gland identification. Normal (left) and hiperplastic glands (right).

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.

C. Image indexing and retrieval

Apart from the automatic extraction of low-level metadata, we still need to design a similarity function In order to retrieve similar images to a given one. This similarity function operates over a vector of selected features, whose composition determines which is the nature of the similarity being considered (similarity is relative in a multidimensional space). Before a similarity measure is computed over the feature vector, the vector should be normalized. We have applied linear scaling unit range normalization. We have tested several similarity measures, such as the popular Euclidian distance, the manhattan distance or the quadratic-form distance. The results of the tests showed that the manhattan and the euclidian distance, in combination with the linear scaling unit range normalization, provide the better performance.

D. MPEG Query Format Interpreter

In order to effectively ensure the interoperability of the system, or any of its modules, with potential third-party applications, we rely on the usage of an standard query interface, ISO/IEC 15938-12:2008 [10][11][12] (MPEG Query Format or MPQF). We have chosen the MPEG Query Format as the search interface of the proposed architecture. MPQF is an XML-based query language that defines the format of queries and replies to be interchanged between clients and servers in a distributed multimedia information search-and-retrieval context. MPQF is an XML-based in the sense that all MPQF instances (queries and responses) must be XML documents. One of the key features of MPQF is that it is designed for expressing queries combining the expressive style of Information Retrieval (IR) systems (e.g. query-by-example and query-by-keywords) with the expressive style of XML Data Retrieval (DR) systems (e.g. XQuery), embracing a broad range of ways of expressing user information needs.

1) Expressing CBIR criteria with ISO/IEC 15938-12:2008

```
<MpegQuery>
  <Query>
   <Input>
     <QueryCondition>
        <TargetMediaType>image/jpeg</TargetMediaType>
        <Condition xsi:type="QueryByMedia">
          <MediaResource xsi:type="MediaResourceType">
            <MediaResource>
              <InlineMedia type="image/jpeg">
                <MediaData64>R0lGODlhDw…</MediaData64>
              </InlineMedia>
            </MediaResource>
          </MediaResource>
        </Condition>
     </QueryCondition>
   </Input>
  </Query>
</MpegQuery>
```

Code 1: *QueryByMedia* example

In ISO/IEC 15938-12:2008, the CBIR criteria can be formulated in several different ways. The CBIR's query-by-example technique relies in expressing user information with one or more example digital objects (e.g. an image file). Low-level features description instead of the example object bit stream is also considered query-by-example, in MPQF these two situations are differentiated, naming *QueryByMedia* to the first case (the digital media itself) and *QueryByDescription* the second one. In the first case is the query processor who decides which features to extract and use, and in the second case is the requester who perform the feature extraction and selection. The MPQF's *QueryByMedia* type offers multiple possibilities to refer to the example media, as just including the media identifier (a locator such as an URL pointing to an external or internal resource) or directly embedding the image bit stream in Base64 encoding within the XML Query (see example in Code 1).

When the *QueryByMedia* type is used, it is up to the query processor to extract the proper low-level features to perform a similarity search over the index. MPQF does not specify which parameters or algorithms must be applied. In our case image analysis automatic extraction is done whenever possible. The other way to express a CBIR condition in MPQF is the *QueryByDescription* type. While the *QueryByMedia* query type uses a media sample such as image as a key for search, *QueryByDescription* allows querying on the basis of an XML-based description.

E. Search Engine Framework

Once the user information needs have been formalized as an MPQF input query, it is received at the system and processed by the MPQF Interpreter. The MPQF Interpreter translates the query into calls to another pluggable module, the Search Engine Framework, which is responsible of processing the different types of conditions present in a query, i.e. text-based queries, CBIR queries or combinations of both. This design pursues decoupling from the system a functionality which can be implemented by existing information retrieval libraries and databases. The goal is to delegate the evaluation of the query condition tree and the text-based conditions to third-party software which should be also capable to interoperate with our CBIR modules.

In our implementation of the proposed architecture, we have selected Apache Lucene [14] to play the role of the Search Engine Framework. Lucene is a high-performance, full-featured text search engine library developed by The Apache Software Foundation. Since it uses its own optimized index of documents, every OB-CLE image has to be transformed into a Lucene Document and indexed before any search can be conducted. Lucene is essentially a text search engine, it does not natively accept CBIR Queries, but we have been able to extend it with our own CBIR modules while preserving its capability to orchestrate boolean condition trees.

F. Graphic user interface

Figure 4 shows a screenshot of the basic view of the system's GUI. The GUI is Web-based and its design has been tuned for operation from Multi-Touch smartphones with a 3.5-inch (diagonal) screen or bigger. The provided interface allows users navigating and searching over the optical biopsy image database. Users are able to retrieve information about precedent diagnostics by providing an example OB image, by using keywords, or by filtering different fields for structured retrieval.

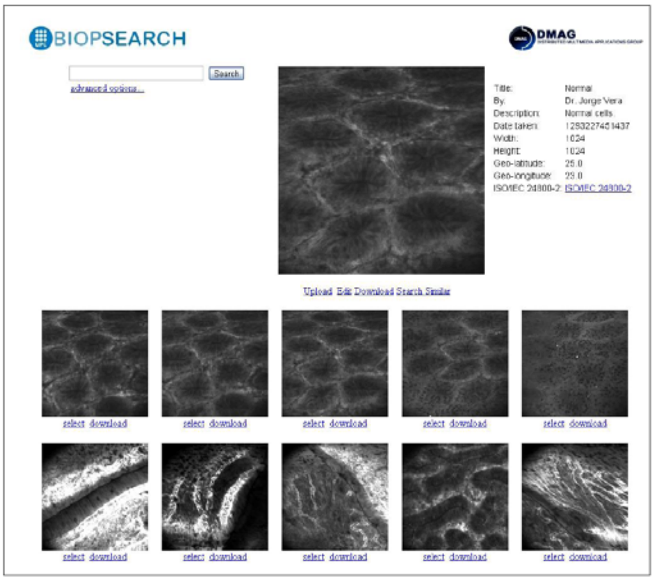

Figure 4. Web interface of the Optical Biopsy Retrieval System

The GUI also allows users performing certain operations over selected OBs, such as cropping, zooming/scrolling, annotating ROIs, highlighting crypts, etc. Figure 5 shows a screenshot of the highlighting crypts view.

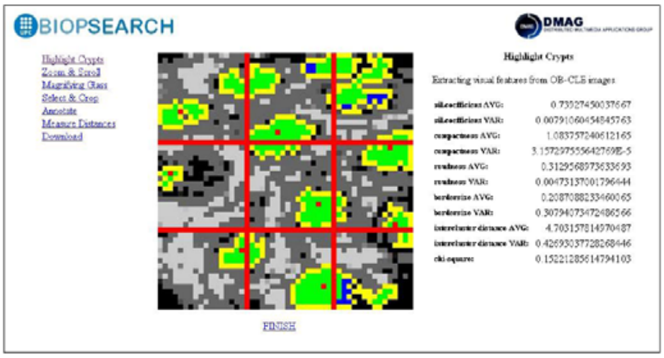

Figure 5. Web interface of the Optical Biopsy Retrieval System

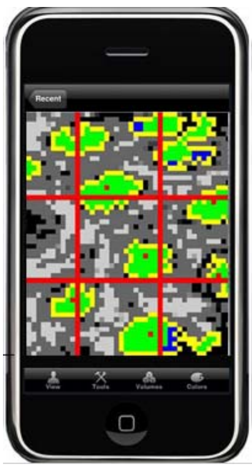

Figure 6. Operating the GUI from an iPhone®

III. Conclusion

The present paper describes the design of an optical biopsy retrieval system based on the query-by-example paradigm and the multimedia standard ISO-15938-12:2008. The system allows users retrieving information about precedent diagnostics by providing an example OB image for content based image retrieval (CBIR), by using keywords, or by filtering different fields for structured retrieval. The system provides a web-based graphic user interface whose design has been tuned for operation from modern multi-touch smartphones. The usage of the system could speed up medical diagnostic knowledge regarding novel technologies. This is the case of OB that is carried out by clinicians (endoscopists) while is based on microscopic morphology of the tissue, a domain specific of the surgical pathology.

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AUTHORS

Ruben Tous received his his Ph.D in Computer Science and Digital Communication from UPF (Universitat Pompeu Fabra, Barcelona, Spain) in 2006. From 2000 to 2001 he worked as a consultant at CapGemini Ernst&Young in Barcelona, From 2001 to 2005 he worked at the Department of Techology of UPF. Since 2006 he is a researcher at DMAG (Distributed Multimedia Applications Group) of the Department of Computer Architecture of UPC (Universitat Politecnica de Catalunya, Barcelona, Spain) and an Associate Professor. He is an expert for the Asociacin Espaola de Normalizacin y Certificacin (AENOR) and has been participating as spanish delegate in ISO/MPEG and ISO/JPEG. His research interests include algorithms and data structures, knowledge representation and reasoning for multimedia understanding, multimedia databases and query languages, multimedia information retrieval and image retrieval in medical applications.

Jaime Delgado. **Ph D**. in Telecomm-unication Engineering since 1987. Telecommunication Engineer since 1983. Since September 2006, Professor at the Computer Architecture Department of the Universitat Politècnica de Catalunya (UPC) in Barcelona (Spain). Previously, Professor of Computer Networks and Computer Architecture at the Technology Department, Universitat Pompeu Fabra (UPF), also in Barcelona, since 1999. Head and founder of the Distributed Multimedia Applications Group (DMAG). Project Manager of several European and national research projects in the areas of electronic commerce, Digital Rights Management, metadata, multimedia content, security and distributed applications. Active participation, since 1989, in International standardisation, as editor of standards and chairman of groups in ISO/IEC, EWOS, ETSI, ITU-T and CEN/ISSS. Evaluator and reviewer for the European Commission in different research programs since 1989. Advisor for the Spanish Ministry of Science. Author of several hundreds of published papers and books, and member or chairman of many Conference International Programme Committees

O.Ferrer-Roca MD. PhD. Born in Barcelona, studied Medicine in the Central University of Barcelona from 1966-1972 with Honors. Got the PhD with “Cariotyping and tissue culture of tumors” in 1974 with Honors. Specialized in Pathology in 1974 being trained in Paris, Milwakee-USA and London.

Working as pathologist in the Clinic Hospital of Barcelona since 1972 got the Assistance Professorship in Pathology in 1974 and the Chair of Pathology of the University of La Laguna in 1982. Commercialized a pathology image analysis system TEXCAN ® ™ specialized in visual textural analysis of the cell chromatin and DNA and immunohistochemical quantification. Founded the CATAI association in 1993, being the president since then. Got the UNESCO Chair of Telemedicine in 1999 for the University of La Laguna. Since 1996 train on Telemedicine the students of medicine and Computer Science, creating the European Master of Telemedicine and Bioengineering applied to Telemedicine in 2004, at distance.

Editor of 8 books and 202 Publications is the author of the first textbook of Telemedicine *Handbook of Telemedicine*. Amsterdam: IOS-Press, 1998, containing the Ontology of Telemedicin