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SPECIALIZED TELEPATHOLOGY ELECTRONIC PATIENT RECORD BASED ON JPEG 2000

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Abstract – This paper proposes a model of Specialized Telepathology Electronic Patient Record (STEPR), exploiting the features of the JPEG 2000 still image compression standard. Among them, coded image encapsulation within a file format structure, inclusion of metadata in this file format, compression efficiency, multiple spatial resolution decompression, signal to noise ratio scalability and region of interest, have been considered as significant for STEPR creation and exchange. The presented STEPR offers a performing, flexible and independent solution, well adapted to a telepathology context, on which critical resources constraints are to be taken into account.

Keywords – Telepathology, Specialized Electronic Patient Record, JPEG 2000.

I. INTRODUCTION

Telepathology can be understood as the branch of telemedicine that deals with the use of telecommunications and information technologies to assist pathologists in the accomplishment of their diagnostic tasks. A more precise definition states that telepathology concerns the exchange of histological and cytological images, as well as their associated patient information, through a suitable communication channel, in order to carry out consultations among pathologists, or physicians and pathologists, situated at two or more remote sites, i.e. urban hospitals and rural health centers [1].

According to this definition, two main sources of medical information take part in the telepathology information exchange process: on one hand, microscopic images acquired from histological or cytological slides at different magnifications; on the other hand, patient related information, which normally comes in the form of plain text. These two medical information sources form the Specialized Telepathology Electronic Patient Record (STEPR). The *specialized* character of the patient record is emphasized, considering the use of only relevant information for image interpretation and cancer diagnostic purposes, as it is normally done in pathology.

Conventionally, the physician or pathologist complete a medical form associated to the patient, after observing a cytological or histological slide under the microscope. Then, both the slide and the medical form are sent to the specialized pathologists, to confirm or correct the preliminary diagnostic, whenever the case is ambiguous or difficult. Such process encompasses hurdles like important delays, risk of slide and medical form damage during their transportation, as well as cumbersome handling of paper and slides together.

We propose to combine one or more digital images acquired from the slide, with specialized patient data using the emerging image compression standard JPEG 2000, in order to significantly improve this procedure by means of a STEPR. Such approach allows a faster information exchange, particularly in critical cases, besides providing a flexible and powerful manner of handling images and patient related information. The described STEPR takes into account users and systems requirements examined in a practical telepathology scenario, on which the goal is to facilitate information exchange between numerous pathology technicians and few specialized pathologists. Those requirements focus on image and patient information flexible and simple manipulation, along with visualization scalability and functionality on available infrastructures.

The rest of the paper is organized as follows. Section II describes the exploited JPEG 2000 features, along with the obtained results. Section III presents the results discussion. Finally, conclusions are presented in section IV.

II. WHY JPEG 2000?

JPEG 2000 is an emerging image compression standard that targets different types of still images: bi-level, gray level, color and multi-component; handled by different imaging modalities. Based on wavelets, among its interesting new features we find: superior low bit-rate performance; compression and decompression of images with various dynamic ranges for each color component; lossless compression to preserve data integrity; image reconstruction with different resolutions; decompression of arbitrary shaped user defined regions of interest; robustness to bit errors in wireless communication channels; content-based description. As we will see in section A, the standard also holds other features that completely fulfill the considered telepathology requirements. It is not our purpose to present an exhaustive description of neither the algorithm used by JPEG 2000 compression, nor the various additional functionalities of the standard. Nevertheless, we present those that are significant to this work. For an overview of the JPEG 2000 compression algorithm the reader is referred to [2].

A. Specialized Electronic Patient Record

One of the most innovative features of the JPEG 2000 standard is the file format structure in which a coded image is encapsulated. While the codestream generated by the compression process specifies the coded image, the file format serves to provide useful information about image characteristics proper use and display. JPEG 2000 offers a

file format known as JP2, which offers the possibility to encapsulate eXtensible Markup Language (XML) formatted metadata. Thus, additional information about the image is given by the metadata, in a more flexible way than predefined-content fields. For instance, it can be used to describe image acquisition conditions (illumination, contrast, etc.). This information can be easily extracted without decoding the image. We have taken advantage of the metadata structure suppleness to format the associated patient data, in the generation of the proposed STEPR.

Fig. 1 describes the STEPR creation. Initially, the patient passes a pathological or cytological test at the doctor's office. For the sake of simplicity, we assume there is already an application that allows the physician to acquire images from histological or cytological slides in a microscope, and capture the patient data by filling an associated digital patient data form. The acquired image is then compressed using the JPEG 2000 algorithm, which generates the corresponding codestream. Simultaneously, the captured patient data undergo a XML formatting process to obtain XML formatted patient data. Fig. 2 shows an example of the resulting XML formatted patient data for an uterus cancer telediagnostic application. Finally, the codestream and XML patient data are integrated by means of a JP2 file, in order to create the STEPR, which can be afterwards stored and exchanged. Notice that the utilization of XML formatted metadata provides flexibility to process and parse the patient data in different ways, from standalone applications to applets embedded in web pages.

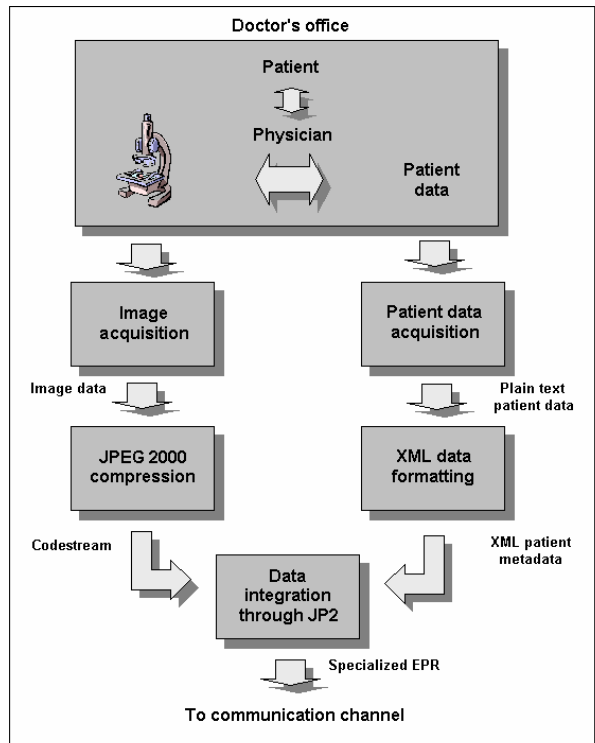


Fig. 1. Telepathology specialized EPR generation.

The generated STEPR can contain one or more images. Given that these are color images, in both cases all the images corresponding to a specific patient can be compressed within the same JPEG 2000 file, exploiting the multi-component image support of the standard. A single RGB image, which has 3 components, is decomposed in three bands, being the sequence of all bands treated as a single multi-component image. Several RGB images associated to the same patient are treated as a multi-component image whose bands 1 to 3 correspond to the first image, bands 4 to 6 correspond to the second image, and so on. Furthermore, the standard offers the possibility to compress each band at different bit rates. As for a single image, when a group of images is compressed in a file, patient data are integrated by means of JP2, as XML formatted data. An additional label in the XML data set indicating the number of images contained in the STEPR can be added for decompression purposes (fig. 2).

```

<?xml version="1.0" ?>
- <epr>
<number-images>3</number-images>
- <form>
- <patient>
<first-name>Aude</first-name>
<last-name>LeGoff</last-name>
<age>26</age>
<address>34 rue de Jean Jaures Brest</address>
<telephone>56 59 01 85</telephone>
</patient>
- <record>
<test-frequency>1 year</test-frequency>
<post-abortion>No</post-abortion>
<post-menopause>No</post-menopause>
<use-hormonals>No</use-hormonals>
<use-diu>No</use-diu>
<pregnant>No</pregnant>
<last-period>12 July 2002</last-period>
<exploration>Healthy uterus</exploration>
<material>Citobrush</material>
<technician-id>pej600319-7643</technician-id>
<date>16 July 2002</date>
<risk-factor>Smokes</risk-factor>
</record>
- <diagnostic>
<test-quality>Adequate</test-quality>
<date>17 July 2002</date>
<result>Negative</result>
<hpv>No</hpv>
<herpes>No</herpes>
<chlamydia>No</chlamydia>
<trichomonas>No</trichomonas>
<bacteria>Yes</bacteria>
<specialist-id>esa550828-6537</specialist-id>
</diagnostic>
</form>
</epr>

```

Fig. 2 XML formatted patient data for an uterus cancer telediagnostic application.

Depending on the specific needs of users having access to the STEPRs, involved telepathology applications can take advantage of JPEG 2000 special features and functionalities to decompress and display images in multiple ways. In that sense, the use of this standard allows the development of well-adapted applications, while fulfilling information

standardization requirements. These special features and functionalities are described in section B.

B. Significant features and functionalities

Compression efficiency

Compression efficiency is essential for telepathology since it allows decreasing the necessary image storage resources and required bandwidth, to exchange images through a communication channel. From the compression point of view, JPEG 2000 represents an improvement compared to its predecessor JPEG, since it provides lossless and lossy compression in one integrated algorithm.

A study of JPEG 2000 efficiency for lossless and lossy compression compared to other available standards showed that for lossy compression JPEG 2000 outperforms all other algorithms (lower PSNR for the same bitrate), while it achieves reasonable compression ratios (around 2.3) for lossless compression [3]. It means that the standard reaches reasonably high compression ratios, preserving the information contained in the image.

Multiple decompression spatial resolution

JPEG 2000 offers significant flexibility in the organization of the compressed bit-stream, in order to enable decompressing the coded image at different spatial resolutions.

The main interest of this feature for telepathology applications is that it offers the possibility to manipulate the same image or set of images, according to available system resources. Therefore, scalable access can take place displaying high or low spatial resolution images, depending on bandwidth or storage constraints. Fig. 3 shows an example of this feature, namely a mosaic containing a cytological image decompressed using four different spatial resolutions.

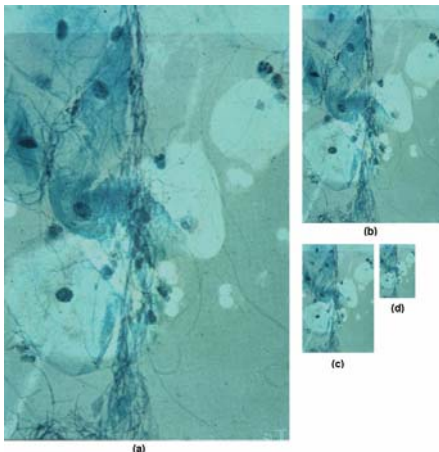


Fig. 3. JPEG 2000 cytological image decoded using different spatial resolutions: (a) 422 x 640 (b) 211 x 320 (c) 106 x 160 (d) 53 x 80.

Signal to Noise Ratio scalability

Also as a result of the bit-stream organization flexibility, JPEG 2000 allows SNR scalability. The decoder can cease

decoding at any truncation point in the codestream and still produce exactly the same image that would have been encoded at the bit-rate corresponding to the truncated codestream. Thus, SNR scalability is the ability to decode an image at a bit-rate different of the one used during compression. Obviously, maximal decompression bit-rate is limited by the compression bit-rate.

Although apparently unrelated to telepathology, this feature could represent an advantage in applications requiring image processing and visualization at different decompression bit-rates. For instance, an application could allow a pathologist to browse image thumbnails decompressed at a lower bit-rate, than the one used to display the image selected for a detailed analysis. The application could also carry out differentiated decompression bit-rates depending on the processing capabilities of the system on which it is executed.

Region of Interest

JPEG 2000 also offers the capability to encode certain portions of the image (called the Region Of Interest or ROI) at a higher level of quality relative to the rest of the image (called the background). This is a desirable functionality for a telepathology application. Making use of it, a pathologist can only preserve the quality of interesting image regions. The background is compressed at a lower quality, reducing the file size and, hence, the required infrastructure for storage and transmission.

Fig. 4 shows a JPEG 2000 cytological image for which a circular ROI having a radius of 100 pixels, located at the center of the image was selected. A 0.1 bits per pixel bitrate was used for the background while the ROI was coded applying lossless compression.

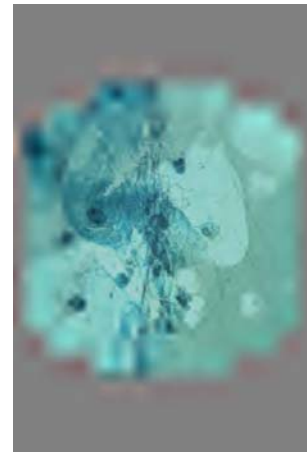


Fig 4. JPEG compressed cytological image containing a circular ROI (radius = 100 pixels).

Error resilience and security issues

Telemedicine applications frequently make use of error prone and non-trusted communication channels, endangering information integrity and patient privacy. In that sense, telepathology is not the exception. As a consequence, error

resilience and security methods in the information transmission are strongly desirable. The JPEG 2000 standard part 1, considers several approaches to error resilience. These approaches are based on error detection and Quality of Service transmission, to guarantee visual information correctness for received images.

Regarding security issues, watermarking in the JPEG 2000 domain has been proposed. Although it is not a part of the standard, watermarking could be applied to avoid unauthorized use of the images [4].

C. JPEG 2000 and telepathology

In our case as in most telemedicine applications, images and patient data should be exchanged under critical transmission, storage and resources constraints. It is therefore necessary to note that even if it can be tailored to cope with some system requirements [5], JPEG 2000 primary objective is not to allow interoperability between medical systems from different vendors. As a consequence, the issue of connectivity and medical information exchange between imaging systems is not relevant to our work. Yet, it is necessary to evaluate if the standard is a suitable solution for a telepathology scenario.

JPEG 2000 completely holds the following features: compression, ROI coding, SNR scalability, multiple spatial resolution, metadata and error resilience. Moreover, it is open and can be exploited using existing or simplified infrastructure, diminishing the dependence on proprietary technology, as well as the costs of required resources, combined with improved performance. Consequently, it seems adapted for the exchange of medical information under constrained transmission and system conditions.

III. DISCUSSION

Considering the exploitation of the features that have been presented, it seems clear that JPEG 2000 is a remarkable alternative for the generation, use and manipulation of a STEPR. The standard can be applied to adequately handle the two kinds of information contained in a typical STEPR (i.e. histological and cytological images, and patient data). Additionally, it holds special features that medical information processing applications can take advantage of, in order to manipulate this information in different, very flexible manners. Among these features we find SNR scalability, multiple spatial resolution decompression, and ROI coding. Its appropriate utilization can have a benefic impact on the global performance of a telepathology application, reducing its infrastructure requirements and dependence on proprietary technology.

One of JPEG 2000 interesting features is the possibility to include metadata (as XML formatted data) in the image file format. Such feature allows the correct generation of the STEPR by integrating patient data to the same file. The main advantage we find in a STEPR based on JPEG 2000 is the flexibility it offers for pathological information

transmission, manipulation and processing without compromising its standardization. Moreover, independently of how many images are contained in the STEPR, only one STEPR file is encoded, stored and transmitted. In our case JPEG 2000 has allowed to define the architecture and functionality of a specific telepathology application according to pathologist real requirements, instead of adjusting them to a proposed product.

Given that in a telemedicine context, information must be exchanged through varying quality communication channels, JPEG 2000 appears to be a suitable solution. Furthermore, it could also be used for internal imaging patient records consultation and manipulation in health care institutions, because of its flexibility, performance and openness.

IV. CONCLUSIONS

JPEG 2000 has been proposed as the base technology for the conception of a Specialized Telepathology Electronic Patient Record (STEPR). This approach is founded on the application of the standard features to a real telepathology scenario. Obtained results show that a JPEG 2000 STEPR is a robust, reliable and flexible solution.

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