DEMOSAICKING AND JPEG2000 COMPRESSION OF MICROSCOPY IMAGES

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ABSTRACT

This paper presents a comparison of original couplings between color filter array demosaicking methods and wavelet compression (JPEG2000). We focus on application handling huge microscopy images (64Kx64K pixels) for telediagnosis. Whereas coding is usually achieved after interpolation, we also consider demosaicking after decompression in order to optimize image quality for a given size of data. We also study the JPEG2000 stream structure for interactive visualization.

Keywords : optical microscopy, anatomical pathology, hematology, demosaicking, JPEG2000, interactive visualization.

1. INTRODUCTION

To capture a color image, a lot of applications are still using single sensor camera with a color filter array introduced by Bayer in 1976 [1]. In the image plane, the chromatic disposition comes from a sub-sampling by a factor of two and a phase difference between red and blue components both in vertical and horizontal directions. The obtained quincunx sampling completes a quincunx sampling of the green component in order to constitute the whole grid of pixels as depicted in figure 1. To compute the three RGB planes from the Bayer pattern, it is necessary to realize an interpolation step, which is commonly called the demosaicking step. This problem is the topic of many recent publications [2, 3]. By the way of an inter sub-band alternating or with the help of an ad hoc post-processing, the typical artifacts like blur effect or the so-called zipper effect should be largely reduced. When these images are incorporated in a communicating system, it is useful to consider that 3 have multiplied their size in bytes. To the best of our knowledge, [4] was the first to introduce globally the problem of the transmission and the rendering of Bayer images. Two possible strategies are then possible: to carry out demosaicking before coding *i.e.* at the sender side or to carry out demosaicking after decoding *i.e.* at the receiver side. Our study relates to precisely these demosaicking-coding couplings.

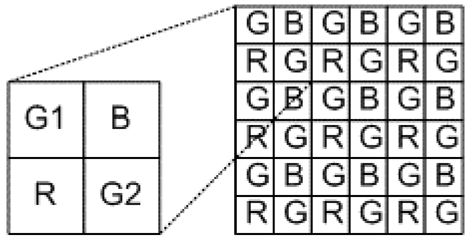

Fig. 1: The Bayer pattern: R, G and B stand for the red, green and blue components. G can be split in G1 (upper left) and G2 (bottom right).

Initially, the work of [4] is proposed within the framework of JPEG-DCT coding of test images. In this paper, we propose to adapt the method to JPEG2000 wavelet coding of very huge images at the greatest possible size, which is 64Kx64K pixels. These last images are the result of acquisitions set in optical microscopy followed by a phase correlation alignment. Their remote consultation exploits the JPEG2000 interactive protocol (JPIP) which is an included part of the standard. In an original way, before source coding, [4] carries out a color transform from RGB to YCrCb domain and a rotation at 45° of the Y component. While thus proceeding, the spatial correlations of the most important component for human visual system, in quincunx at the origin, are increased. No high frequencies are created artificially which allows the rate of statistical coding (a reverse transformation and a demosaicking step are also useful to render the RGB image) to be reduced. However, from a remote consultation point of view, geometric differences between the stored version and the visualized version requires a modification of user request. We propose also in this paper a more simple method that avoids this modification by coding the Bayer image directly and by carrying out demosaicking in the distant terminal. However, for this method, the high frequencies (corresponding to the color planes multiplexing) mean making irreversible compression at relatively high bit rates.

Contrary to classical JPEG, which induces a blocking effect, JPEG2000 wavelet coding doesn't prohibit the edge sensing method. For the comparison, we use the demosaicking method proposed in [5] rather than a bilinear

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interpolation in [4]. After a brief introduction to JPEG-2000 features for interactive application, we present retained couplings in section 3. Comparison results are given in section 4.

2. SOURCE CODING FOR INTERACTIVE APPLICATION

2.1 Core coding system

JPEG2000 is an emerging wavelet based compression standard for still images with the same core system describing both lossless and lossy coding. For wavelet coefficient coding, the EBCOT algorithm (Embedded Block Coding with an Optimized Truncation) provides a rich scalable image stream which allows several progressive modes in transmission and visualization with multiple decompression possibilities. Quality layers (L mode), resolution (R mode), component (C mode) or pixel position in raster scan (P mode) can be selected to order data. User Region Of Interest (ROI) can be also defined as information to be transmitted first. Some ancillary data, such as a medical report, is easily included in XML format [6]. The main advantage of the JPEG2000 is thereby the stream structure. It is completely described in [7]. In a context of telediagnosis, the random access, which corresponds to human browsing on the network, determines the progressive transmission mode. The resolution and raster scan progression (RPCL mode) is the most efficient in data partitioning to support interactivity.

2.2 JPEG-2000 Interactive Protocol (JPIP)

This part of the compression standard focuses on remote interactions with JPEG-2000 contents on the Internet in an efficient and effective manner. With JPIP, a single terminal doesn't systematically access the entire compressed file. Ad hoc requests allow the retrieval of the useful information corresponding to a browser window. More precisely, spatial ROI, resolution, and a component of interest define a JPIP request so that the server provides an optimal response. It is based on the HTTP protocol:

```
GET <resource>?<query> HTTP 1/1
```

As an example:

```
GET images/widefield.jp2?
R=512,640&O=0,0&S=512,478&C=0,1,2
```

is the request of components 0, 1, 2 *i.e.* red, green, blue (C = 0, 1, 2) for the region in the upper left corner (O = 0, 0) at the resolution 512x640 in a user window size of 512x478. Even though the entire test image is here `widefield.jp2` with a size of 25498x34192 pixels, only a few KBytes are transmitted to satisfy the JPIP request. Moreover, a cache management avoids the retransmission of information when a region is requested twice in the same session. The JPIP is therefore convenient for telediagnosis over wide field images in anatomical pathology, hematology and cytology with a low rate transmission link.

3. INTERPOLATION AND COMPRESSION

This section describes the three methods which are retained for the comparison of the demosaicking-wavelet coding coupling. Demosaicking before coding is the conventional solution. It involves both an interpolations of the green quincunx sampling and of the two other components. After demosaicking, components are transformed from RGB space to YC_bC_r, a space that is more convenient for color compression (one achromatic component Y for two chromatic components C_b and C_r). By default, JPEG-2000 coding includes a soft sub-sampling of chromatic components computed by Contrast Sensitivity Function (CSF) weighting factors. The typical hard 2:1 sub-sampling of C_b and C_r is not employed. Here, components are sub-sampled according to resolution levels and a tunable viewing distance. Thus, with the conventional solution, components are up and sub-sampled respectively by the demosaicking and coding processes.

In order to avoid transmitting useless information transmission, the demosaicking step can be done after decoding just in time for color visualization. A simple proposition is to shift every other line of green pixels in the horizontal direction and remove blank columns to construct square sampling. However, artificial high frequencies are created in this case and can be irreversibly filtered at low rates. A lazier method (figure 2) consists in coding the original Bayer image as a monochrome image which is then interpolated. We propose this method for relative high rates (lossless or near lossless coding). At these rates, the wavelet filtering doesn't involve degradation of the modulation between R, G and B channels.

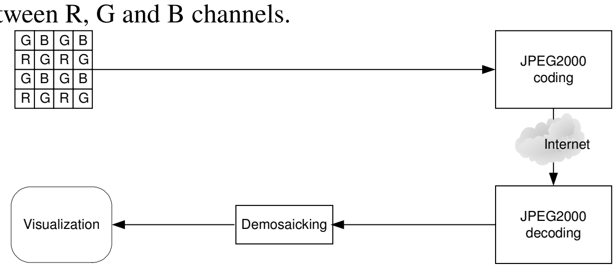

Fig. 2: Processing diagram for the Bayer image coding. Demosaicking is made after decoding.

As another swap with source coding, the proposition of [4] consists in doing a 45-degree rotation of the quincunx grid first and removing blank columns and lines (figure 3).

This non-linear transformation preserves spatial correlation between green pixels with no information increasing per pixel (8 bits per pixel). This algorithm includes a YCbCr irreversible color transform where Y pixels replace green pixels *i.e.* Y1 and Y2 from G1 and G2 of figure 1. Components Cb and Cr are registered in the center of the Bayer pattern at a distance equal to $\sqrt{2}$ of Y pixels. The rotation, which is applied just on the Y component, reveals black corners. Our adaptation to wavelet coding consists in adding a mean value to corresponding pixels. For target bit rates, methods like boundary mirroring don't bring a significant gain in quality.

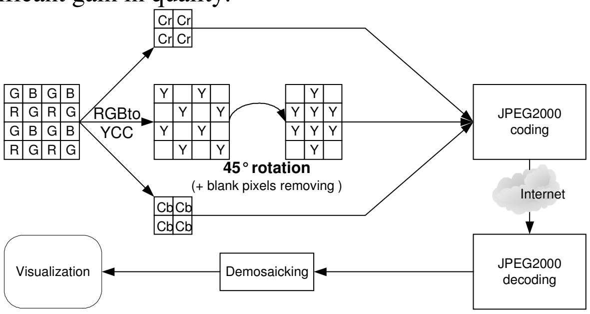

Fig. 3: Processing diagram with 45° rotation of Y component and JPEG2000 coding.

4. COMPARISON RESULTS

4.1 Results

We compare a conventional scheme (demosaicking and irreversible JPEG2000 coding) with two non-standard schemes (*i)* 45° Y rotation and irreversible JPEG2000 and *ii)* irreversible JPEG2000 coding of original Bayer image and demosaicking). Algorithms have been tested on anatomical pathology and hematology images respectively shown on figures 4 and 5 in their interpolated version. Results are given in figures 6 and 7. The original 1310 KB (8 bpp) images have been compressed with a JPEG2000 encoder [8] into two ranges of size: 0 to 1000 KB for anatomical pathology and 0 to 400 KB for hematology. A classical quality assessment is made for a constant size by Peak Signal to Noise Ratio measure (PSNR in dB) in YC_bC_r domain (PSNR-Y and average of PSNR-C_b and PSNR-C_r) which are confirmed by a visual observation.

4.2 Discussion

PSNR-Y is given on the left sides of figure 6 and 7. For a large range of size, the 45° rotation of the Y component gives higher quality than the conventional method (demosaicking and JPEG2000 coding). For anatomical pathology (respectively for hematology), the conventional method, however, gives higher quality below 160 KB (resp. 100 KB) which corresponds to 8:1 (resp. 16:1) in compression ratio. The non linear transform including 45° rotation and the suppression of blank columns and blank lines introduces a reduction of distance between Y pixels from $\sqrt{2}$ to 1. This means more high frequencies or contrast but also degradations in very low bit rates. Fortunately, classical utilization in optical microscopy does not lead to these compression ratio. The contribution of the proposed method within the JPEG2000 framework is also significant on the C_b and C_r quality assessment (on the right sides of figures). But, for these components, the lazy method, which consists in coding Bayer images directly, can provide better PSNR for higher rates. These satisfactory results are computed although the comparison introduces a degradation (round off) for the Bayer image by the irreversible color transform from RGB to YC_bC_r, which is not really used except for the assessment measure. The algorithm behavior is nevertheless highly non-linear since, at low rates, degradations are unacceptable both visually and in terms of PSNR. If we take a look again at the Y quality assessment, coding the Bayer image directly gives higher PSNR than a conventional scheme if the size is greater than the range 200-300 KB in both specialties which corresponds roughly to a 5:1 compression ratio. At these rates, differences are not perceptible with the Y rotation solution, which takes twice the computed time. From a JPIP point of view, HTTP requests need to be modified if Y is rotated since the image that is visualized differs from the server version. This leads to using the lazy method at high rates up to reversible coding.

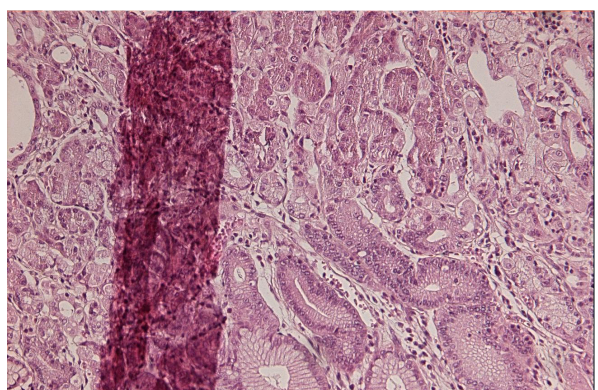

Fig. 4: slide image in anatomical pathology (courtesy of the company TRIBVN) interpolated by [5].

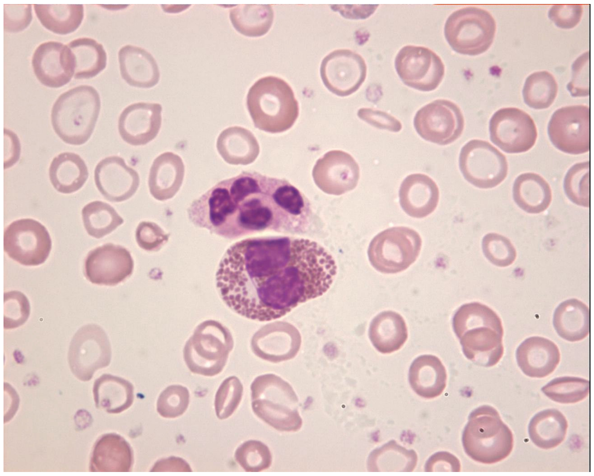

Fig. 5: slide image in hematology (courtesy of the company TRIBVN) interpolated by [5].

5. CONCLUSIONS

We discussed techniques for coupling demosaicking and coding microscopy images. The solution of the quincunx component rotation initially proposed by [4] gives a significant gain of quality at high compression ratio (< 5:1) for a medical application. However, for lower compression ratio, coding the Bayer image directly with JPEG2000 is competitive in terms of image quality. Moreover, by this method, we preserve the structure of the JPEG2000 stream and its associated interactive protocol, which allow an optimal random access suitable for telediagnosis applications.

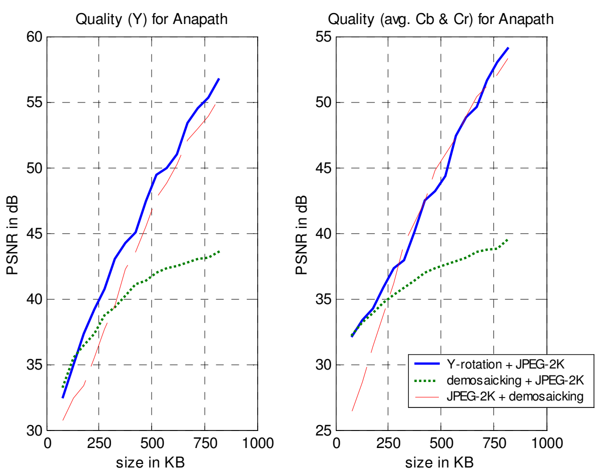

Fig. 6: Rate/Quality analysis for anatomical pathology images

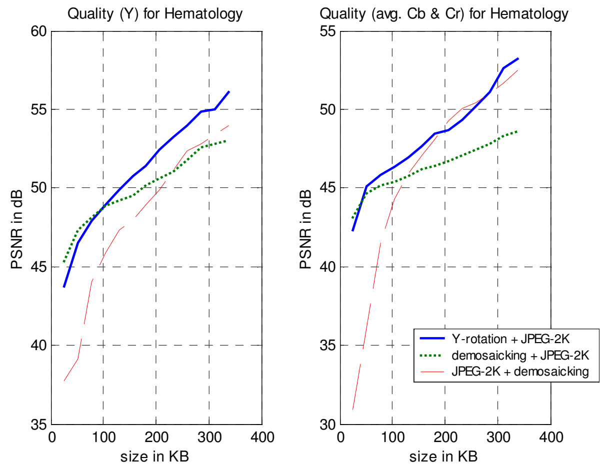

Fig. 7: Rate/Quality analysis for hematology images

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