

Region Of Interest coding applied to Map Overlapping in Geographic Information Systems

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Abstract—Geographic Information Systems (GIS) and Remote Sensing (RS) applications are becoming an important issue for the territorial management, governmental and research projects, and for many fields of our society. A characteristic of such applications is the displaying of successive layers of information that, in some cases, may overlap areas of the displayed images that are eventually never showed to the final user of the application. Even though these overlapped areas are of null interest, the coding of these images considers the complete area of the image, and thus the coding performance of the compression system is penalized. This paper introduces a novel use of the Region Of Interest (ROI) coding techniques to overcome the drawbacks of the map overlapping in GIS and RS applications. The proposed approach is based on a ROI coding method defined for the JPEG2000 standard that efficiently improves the coding performance and keeps JPEG2000 compliance.

I. INTRODUCTION

Geographic Information Systems (GIS) represents real world objects using two main data types: rasters and vectors. A raster consists of a matrix of cells, where each cell contains a discrete or a real number. The most common data stored in rasters are images, although other information, such as rainfall, slopes, etc., can also be stored. A vector represents some kind of geometric data, such as points, lines or polygons, that can represent objects. Displaying geographic information in a GIS generally means overlapping different rasters and vectors and, in most cases, some areas of the image raster, which is displayed as the background, are covered by vectors.

On the other hand, some image-based applications have the need to enhance the quality of specific regions over the rest of the image. For instance, in Geographic Information Systems and in Remote Sensing (RS), images may contain regions more meaningful than others; in the remote browsing of images, the improvement of the quality of specific regions is also beneficial.

The technique used in coding systems to enhance specific regions of an image over the rest of the image (the background) is called Region Of Interest (ROI) coding. Through the use of ROI coding, when the code-stream is decoded at increasing bit-rates, the prioritized regions (ROIs) are decoded

at a higher quality than the background. This is useful, for example, when the image needs to be transmitted over the network, since those image regions that have more interest are rapidly decoded at a high quality, even if only a small portion of the code-stream is transmitted.

The JPEG2000 standard, developed by the Joint Photographic Experts Group, is an image coding system that provides advanced features such as: state-of-the-art coding performance, five different progression orders, random code-stream access and processing, and scalability by quality, resolution, component and spatial area. JPEG2000 is constituted by different 12 parts, addressing different issues of image and video coding, transmission and security and it fulfills most of the requirements and needs of image applications. Part 1 [1] and Part 2 [2] of the standard contain, respectively, the core coding system and some extensions. Both parts contain one ROI coding method.

The purpose of this research is to improve the coding performance of the images containing overlapped areas to enhance the browsing experience in GIS and RS applications. This is carried out by means of a novel use of a ROI coding method defined for the JPEG2000 standard. The proposed approach keeps JPEG2000 compliance, does not require significant changes of the coding system and, in addition, it widely reduces the size of the final code-stream.

This paper is structured as follows: Section II reviews the ROI coding methods used in JPEG2000, pointing out their main features; Section III introduces our approach, and Section IV reports some experimental results. Section V concludes this work pointing out some remarks.

II. ROI CODING IN JPEG2000

The JPEG2000 core coding system has three main coding stages. In the first stage the image information is efficiently decorrelated through the application of the Discrete Wavelet Transform (DWT) and the image coefficients are quantized through a dead-zone quantizer. The second stage is called tier-1 coding and encodes small blocks of wavelet coefficients, called *code-blocks*, using a fractional bit-plane coder and the

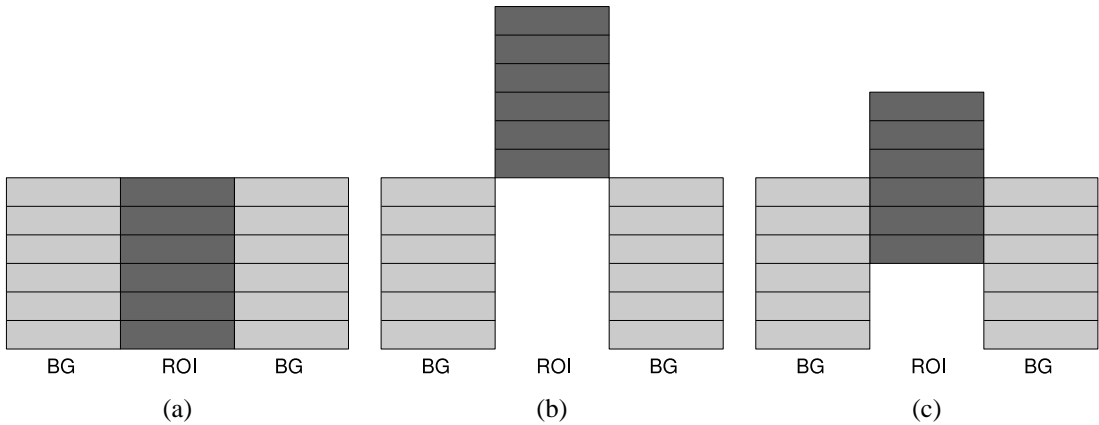


Figure 1. (a) Original image, (b) MaxShift ROI coding method, with $s = 6$ (c) Scaling-Based ROI coding method, with $s = 3$.

MQ arithmetic coder. The third stage is the tier-2 coding and it reorganizes the code-streams produced by the previous stage, constructing layers of increasing quality that are embedded in the final JPEG2000 code-stream.

We classify the JPEG2000 ROI-coding methods depending on where they are applied within the coding system. We propose two categories: the methods that prioritize ROIs by modifying the wavelet coefficients (operation carried out just before the tier-1 coding stage) and the methods that use the rate-distortion optimization mechanisms of JPEG2000 to enhance the ROI areas over the background.

A. ROI-coding based on the scaling of coefficients

Two of the methods defined in this category are included in the standard: the MaxShift and the Scaling-Based, which are respectively defined in Part 1 and Part 2 of JPEG2000 [3]. The main idea behind these methods is to up-shift the wavelet coefficients within the ROI, benefiting from the fact that the tier-1 stage codes the coefficients in a bit-plane by bit-plane fashion. The main difference between the MaxShift and the Scaling-Based method is that the former up-shifts all ROI coefficients over the background, whereas the latter allows different priorities in order to finely combine the coding of ROI and background. Figure 1 shows an example of MaxShift, and Scaling-Based, with a priority of $s = 3$.

The ROIs defined through the MaxShift method can be specified with an arbitrary shape, which is identified by the decoder through the scaling factor s , whereas for the Scaling-Based method, the shape of the ROIs must be specifically transmitted and is restricted to rectangular or ellipsoidal shapes.

Other methods of this category proposed in the literature are the Hybrid Bitplane Shift [4], and the Generalized Partial Bitplane Shift [5], both prioritizing a specific number of ROI bit-planes and allowing different strategies for the combination of ROI and background. All the methods of this category penalize the coding efficiency, since the number of bit-planes to be encoded is increased by the scaling factor. Besides, once the code-stream is already encoded, the ROIs can not be modified without a complete re-encoding of the image.

B. ROI-coding based on rate-distortion optimization

The ROI coding methods defined in this category benefit from the code-stream organization in layers of increasing quality to allocate the ROIs in the first layers. This is carried out by means of the rate-distortion optimization methods defined in the coding system. The first method of rate-distortion optimization defined for JPEG2000 was the Post Compression Rate-Distortion Optimization (PCRD-Opt), defined in [6], and the first ROI coding method of this category was the Implicit ROI coding [7, Chapter 16.2], which uses the PCRD-Opt applying different rate-distortion weights to the code-blocks that belong to the ROI.

More recently, slight variations of the Implicit ROI have been proposed in [8], [9]. The purpose of the former is to enhance the visual results reducing the priority of the background coefficients by the truncation of some bit-planes. The latter allows a precise definition of ROIs within code-blocks.

The methods of this category do not penalize the coding performance and allow the modification of the ROIs without needing to re-encode the image. However, the ROIs can only be defined by the rectangular shapes of code-blocks and the combination of ROI and background is not as precise as with the methods of the previous category.

III. MAP OVERLAPPING IN A GIS APPLICATION

The overlapped areas of the images, never displayed in GIS, contain information that in a standard compression are encoded and stored to the final code-stream. Coding systems could avoid the coding of these areas in order to improve the coding performance and reduce the bit-rate of the final code-stream. Although most coding systems do not address this issue, the ROI coding can be used to overcome the drawbacks of the map overlapping. The main idea behind this approach is to consider the non-overlapped areas as the ROI and stop the coding process before the encoding of the background.

Among the ROI coding methods reviewed in the previous section, the MaxShift method is the most adequate one to be

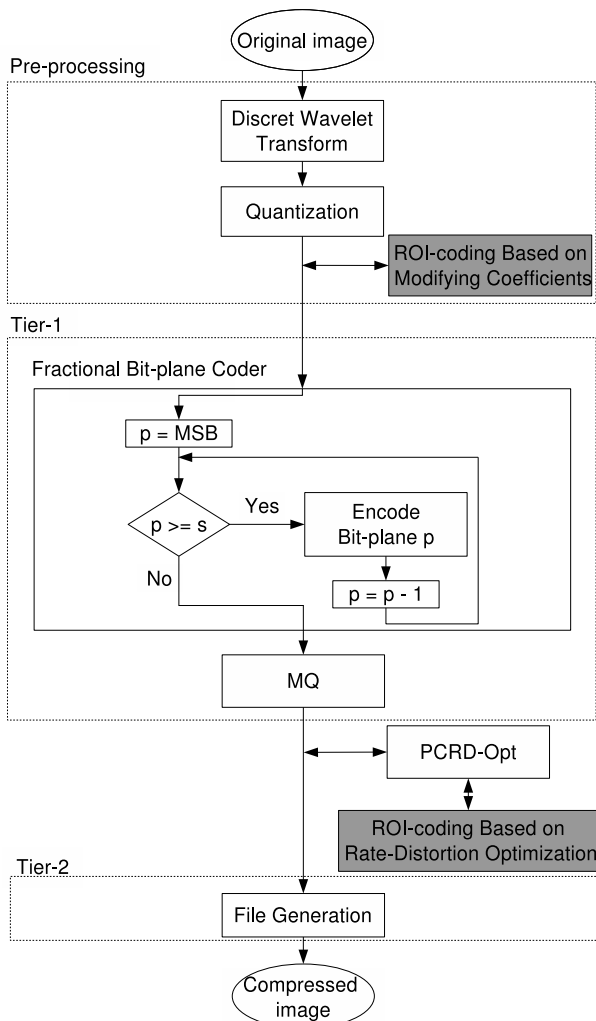


Figure 2. Proposed approach. The tier-1 stage is slightly modified.

applied, since it allows the definition of arbitrary areas without needing to transmit them separately, and since it completely encodes the ROI before the background.

MaxShift works as follows: once the ROI shape is specified, it computes the scaling factor needed for the wavelet coefficients by $s = \lceil \max(\log_2 |y[n]|) \rceil$, where $y[n]$ are the wavelet coefficients belonging to the background and $\lceil \cdot \rceil$ denotes the ceiling operation. To stop the coding process once the ROI coefficients are encoded, the tier-1 coding must be slightly modified to encode only the bit-planes in the range of $[MSB, s]$. This modification is depicted in Figure 2.

Note that with this simple modification the final code-stream only contains the coding belonging to the ROIs and the ROI shape is implicitly transmitted to the decoder. This allows a significant reduction of the final code-stream bit-rate, reduces the computational load of the coder and keeps JPEG2000 compliance.

IV. EXPERIMENTAL RESULTS

To evaluate the coding performance achieved by the proposed method and a standard compression, we use an ortoin-



Figure 3. Image containing overlapped areas, size 1024×1024 . The overlapped areas cover 41% of the image.

age image provided by the Cartographic Institute of Catalonia (ICC) [10] of an area of Barcelona, with a size of 1024×1024 . This image is used in the GIS application MiraMon [11], which also displays vectorial information belonging to the buildings of the area, extracted from the 1:5000 topographic map also provided by the ICC. The image that is eventually displayed in the application is showed in Figure 3. The overlapped image area, i.e. the area that is never showed to the final user, covers 41% of the image. The proposed method for coding of images with Map Overlapping has been applied using our BOI implementation [12] of JPEG2000.

The experiments have been carried out encoding¹ the image at 62 different target bit-rates, decompressing it and comparing with the non-overlapped areas of the original image in terms of Peak Signal to Noise Ratio (PSNR). Table I reports the results, in terms of PSNR, at some target bit-rates for the original coloured image at 24 bits per pixel (bpp) and for the gray-scaled image at 8 bpp.

It is worth noting that the use of the proposed method widely enhances the quality of the image when compared to a plain compression. At 1 bps, for example, the improvement obtained with the gray image is as much as 2.45 dB, and at higher bit-rates the improvements are even better. Besides the PSNR improvement, when the complete encoding is carried out, the proposed method is able to reduce by 37% and 35.5% the code-stream bit-rate, respectively for the gray and colour image.

¹Coding parameters are: lossy compression, 5 wavelet transform levels, code-block size of 64×64 , derived quantization and the restart coding variation.

Table I
PSNR (IN DB) OF THE NON-OVERLAPPED AREAS AT DIFFERENT BIT-RATES. ROI COLUMNS SHOWS THE RESULTS WHEN THE PROPOSED TECHNIQUE IS APPLIED. STANDARD COLUMNS SHOWS THE RESULTS WHEN APPLYING A STANDARD COMPRESSION.

bit-rate (bps)	gray-scaled image		colour image	
	ROI	Standard	ROI	Standard
0.125	21.84	21.63	21.52	21.30
0.25	24.74	23.90	24.04	23.33
0.5	28.26	26.88	26.87	25.89
1	33.00	30.55	30.52	28.95
2	42.57	36.10	35.91	32.67
3	50.20	41.72	40.37	36.17

V. CONCLUSION

Taking into account that the images displayed in GIS and RS applications may have overlapped areas that are never displayed, this paper introduces a novel use of ROI coding addressed to enhance the browsing experience of the final user of these applications by improving the coding performance. The proposed technique uses one of the ROI coding methods defined for JPEG2000 and, as the experimental results suggest, it achieves a significant coding performance improvement and widely reduces the bit-rate of the final code-stream.

An important point of the proposed approach is that it keeps JPEG2000 compliance. Although shape-adaptive methods proposed in the literature [13], [14], [15] could also address the map overlapping of GIS and RS application achieving better coding performance, they do not keep JPEG2000 compliance and, furthermore, they require important modifications on the coding stages.

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