LOSSLESS COMPRESSION OF BAYER ARRAY IMAGES USING MIXED-LATTICE LIFTING TRANSFORMS

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To my Parents, my Sisters and my Friends

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Abstract

Over the past few decades, digital image compression has been a hot area of research, and with the development of new media storing devices, fresh image compression schemes have arise. Among the digital data processed nowadays, images have become very popular, for their characteristic of being able to represent content information in a vast number of approaches.

In this study a lossless compression method to compress Bayer images using mixed-lattice transforms is presented. With help of the Lifting scheme and its perfect reconstruction characteristics, a lossless compression method is able to be performed.

The transform coefficients are entropy coded with a Golomb-Rice coder that models well the probability distributions of these coefficients. The Golomb-Rice coder is made adaptive through the update of parameter k that determines the length of the codewords. The adaptation is done using local statistics of previously encoded data.

By separating the image in three different Bayer components and adapting a second generation wavelet, higher compression ratios than JPEG-LS were obtained. The algorithm is simple enough to achieve an average of twenty one computations per pixel, and because it has a memory less characteristic it can be employed in systems with low storage capacity.

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Chapter 1: Introduction

The main goal in this study is to create a method to lossless compress images, these may contain very valuable information and the loss of information is not accepted. They are transformed and then compressed in a special three-line-scan. The outcome is a very low computing scheme that performs at acceptable bit rates, exceeding JPEG-LS standard bit rates. The accomplishment of lower number of computations per pixel is translated in energy savings for the system that employs low processing microcontrollers.

1.1 IMAGE COMPRESSION HISTORY

Image compression has been an area of study that has been explored for several decades. Towards the end of the eighties, digital imaging became more popular. This is one of the main reasons why several compression standards began to be created. Some of the existing image formats are: FAX Committee Consultative International Telephonic and Telegraphic (CCITT) 3, Graphics Interchange Format (GIF), Joint Photograph Experts Group (JPEG), Bit Map Picture (BMP) and Tagged Image File Format (TIFF) [35].

The principal idea of image compression is to decrease the amount of redundant information contained on an image, so as to allow a more efficient way to store or transmit it. The main objective in is to preserve the best image quality at high compression ratios.

The image compression techniques can be separated in two different methods: lossy and lossless compression. In lossy techniques quantization is performed to increase the compression ratios at the expense of image quality. Lossless compression methods retain all the information in the image but usually achieve no more than a two to one compression ratio. They are preferred when the information has more valuable content, such as medical imagery [36] or image scans made for records and documents.

JPEG is another type of format used in digital photography, and it is known to be the most popular among the other compressing and storing formats, it is mainly used by the World Wide Web users and it is also the most popular in digital cameras. It was created in the late 80s by the Joint

Photography Experts Group. JPEG is the common name of the ISO/IEC IS 10918-1 ITU-T Recommendation T.81 published in September 1992. It is based on the 8x8 Discrete Cosine Transform, zigzag scanning, uniform scalar quantization and Huffman coding [39].

JPEG-Lossless (JPEG-LS) is a standard for image compression created from the LOCO-I compression scheme and stands for LOw COmplexity algorithm. JPEG-LS is a lossless method that uses an adaptive non-linear predictor, together with context modeling and a Golomb coding. JPEG-LS was developed with the aim of providing a low-complexity "near-lossless" image compression standard that could offer better compression efficiency than lossless JPEG.

JPEG2000 is a standard based on wavelets. It was created by the Joint Photography Experts Group in 2000 and it was intended to replace the previous JPEG standard. JPEG2000 takes advantages of advanced wavelet technologies: integer wavelets and lifting schemes, context-based, binary arithmetic entropy coding and rate-distortion optimization [35].

In digital image applications, image resolution is limited by the camera sensor. Common sensors are: Charge-Couple Devices (CCD) or Complementary Metal-Oxide Semiconductors (CMOS). These sensors transform the light into discrete signals, replacing the film used in analog photography. A CCD device consists of a large number of light-sensing elements arranged in a two-dimensional array on a thin silicon substrate. The silicon semiconductor has the property to allow the CCD chip to trap and hold light. The pixels are classified in the silicon layer placed on the chip by an orthogonal grid of thin transparent strips that hold the electrodes. These are also called gates [37].

Numerous digital cameras use raw format, which is the unprocessed information taken from the sensor. Raw data is formatted as tiny individual colors, commonly obtained after processing the image through a Bayer filter. This process separates Green, Red and Blue color information in a special grid configuration. More details are discussed in Chapter 2.

Several manufactures process the raw data to create personalized compatible information, e.g., Nikon Electronics uses NEF format, Canon employ CRW or CR2 and Minolta make use of MRW. Recently, Adobe Systems has released the Digital Negative format (DNG), a royalty free raw image format which has been adopted by few camera manufacturers [38].

At the beginning raw formats had to be processed by dedicated image editing software such as Adobe Photoshop. Nevertheless, over the years some other software with raw format support has risen, e.g., Google's Picasa. By using this types of software several settings may be modified, such as, white balance, exposure compensation, color temperature, etc. In other words, raw format allows the user to manipulate the information without losing the original image properties.

1.2 Image Formats for Raw Sensor Data

This section describes some of the most important work done on image compression of Bayer images in previous years.

Toi and Ohita presented a subband coding technique suitable for image compression in a single CCD camera with a Bayer Color Filter Array (CFA). In it, they have applied a Symmetric Short Kernel Filter (SSKF) both horizontally and vertically to red and blue color signals, and a two dimensional perfect reconstruction filter to green color signals [1]. The performance obtained was better than the one acquired with Differential Pulse Code Modulation (DPCM) and Hadamard transform. However, the computational complexity is higher than the other methods.

Sang-Yong Lee and Antonio Ortega [2] give a reversible image transformation. The Red Green Blue (RGB) image is transformed to Luminance and Chrominance components (YCbCr) first. Then, Y data array is rotated into a rhombus, and finally, the rotated Y data and original Cb and Cr data are separately compressed by JPEG. However, the rotated Y data is not rectangular so that the standard raster scan used as in JPEG-LS cannot be applied directly [20].

In 2003, Koh, Mukherjee and Mitra [3] presented two new methods: structure conversion method and structure separation method. The structure conversion method can provide lower computational complexity, as well as very good compression performance. But the CFA data is low-pass filtered in YCbCr space, which leads to image quality loss [20]. The structure separation method allows high image quality at high compression ratios [3].

Color correlation is often employed to recover missing values, King-Hong Chung and Yuk-Hee Chan presented in [21] a paper that shows how green samples from a Bayer image are recovered from blue and red planes. This algorithm can effectively preserve the details in texture regions and, at the