SCAN BASED LOSSLESS IMAGE COMPRESSION SCHEME

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ABSTRACT

In this paper we propose a new lossless image compression method. The suggested method relies on novel selective scan process that aims to scan the image in the direction where minimal pixels intensity change is recorded. Such scan process would reduce high frequency data, in order to provide a smooth and high correlated mono-dimensional signal easy to compress. This scan process is followed by an adapted coding scheme based on DPCM and Huffman algorithms. The suggested method shows a significant compression improvement compared to classic conventional lossless coding schemes such as GIF and PNG.

Index Terms— scan, lossless, image, coding, signal, frequency, correlation.

1. INTRODUCTION

Image compression addresses the problem of reducing the amount of data required to represent a digital image. It is a process intended to yield a compact representation of an image in order to reduce the image storage/transmission requirements. Compression is achieved by the removal of one or more of the three basic data redundancies:

1. Coding Redundancy
2. Interpixel Redundancy
3. Psychovisual Redundancy

Coding redundancy is present when less than optimal code words are used. Interpixel redundancy results from correlations between the pixels of an image. Psychovisual redundancy is due to data that is ignored by the human visual system (high frequency component).

Image compression techniques reduce the number of bits required to represent an image by taking advantage of these redundancies [1].

The image compression techniques are broadly classified into two categories depending whether or not an exact replica of the original image could be retrieved from the compressed image.

These categories are:

1. Lossless technique
2. Lossy techniqhe

In lossless compression techniques, the original image can be perfectly recovered from the compressed image.

It is also known as entropy coding since it use statistics techniques to minimize redundancy [1,4]. Because of its low compression capability, lossless compression is used only for a few applications with stringent requirements such as medical imaging [4]. However, lossy schemes provide much higher compression ratios than lossless schemes. That is why lossy schemes are widely used since the quality of the reconstructed images is somehow adequate for many applications. By this scheme, the decompressed image is not identical to the original image, but reasonably close to it [2, 3].

Although their compression ratios superiority compared to lossless image coding schemes, lossy compression one are not used overall. Some critical applications do not support any loss of information such as medical and satellite image where any details is important. In such applications, lossless image compression is a crucial need and so their performance improvement.

Technically, the difference between the two classes is the psychovisual redundancy elimination.

These redundancies present high frequency which is generally hard to compress. As it is usually ignored by human visual system, their elimination is allowed in lossy coding context which is not the case in lossless coding one. Therefore, in order to improve the compression efficiency of lossless coder, some researches try to reduce these psychovisaul redundancies by exploring different scan methods capable to more explore image correlation [5-7].

In this context, we propose a lossless image coding scheme based on a new scan strategy that attempts to explore image correlation. The suggested method proceeds in tow steps:

1. Image scanning: the image is divided into isometric square blocks in order to explore local image autocorrelation, and then each block is analyzed in order to estimate the minimal pixels change direction. Then the block will be scanned using adequate suitable scan in order to generate 1D smooth signal.
2. Coding: the generated signal is DPCM and huffman coded.

In addition of its significant compression improvement compared to classic conventional lossless coding scheme the suggested method presents several advantages. First, the method is conceptually simple; it relies on conventional basic concepts. Second, it presents a low complexity processing. Third, it supports parallel processing. All this make easier its integration and its implementation in software and hardware design.

Section 2 gives an overview on conventional lossless coding techniques. In Section 3 we present the motivation behind the proposed approach. In section 4, we detail the proposed scheme. In section 5 we discuss compression efficiency of the proposed method. We conclude with a short summary.

2. LOSSLESS CODING

GIF and PNG are the most prevalent lossless image compression techniques. A concise overview of GIF and PNG image compression techniques is described below:

2.1. Graphics Interchange Format (GIF)

The Graphics Interchange Format (GIF) is a lossless 8-bit-per-pixel bitmap image format that was introduced by CompuServe in 1987 [8, 9]. GIF images are compressed using the Lempel-Ziv-Welch (LZW) coding [15, 16], a dictionary-based technique to exploit redundancy. The initial size of dictionary is 2^9, while this fills up, the dictionary size is doubled, until the maximum dictionary size of 4096 is reached. Afterwards the compression algorithm behaves like a static dictionary algorithm. A more detailed description can be found in [10, 11]. GIF is widely used for lossless compression of both natural and synthetic images. While GIF works well with synthetic images, and pseudo color or colormapped images, it is generally not the most efficient way to compress natural images, photographs, satellite images [12]. LZW coding, used in GIF, scans pixels from left to right, top to bottom. Therefore, horizontal patterns are effectively compressed but vertical patterns are not [17].

2.2. Portable Network Graphics (PNG)

Portable Network Graphics (PNG) is a bitmap image format that employs lossless data compression. PNG was created to improve upon and replace the GIF format, as an image-file format not requiring a patent license [13]. The compression algorithm used in PNG is based on LZ77 [18], a dictionary-based compression technique. PNG uses *deflate* [19] implementation of LZ77. At each step the encoder examines three bytes. If it cannot find a match of three bytes, it abandons the first byte and examines the next three bytes. So, at each step it either abandons the value of a single byte, or a literal, or a pair _*match length*, *offset*_. The alphabets of the *literal* and *match length* are combined to form an alphabet of size 286 (indexed between 0-285). The indices 0-255 represent literal bytes and the index 256 is an end-of-block symbol. The remaining 29 indices represent the codes for ranges of lengths between 3 and 258. A more detailed description and standard tables for representation of *match length* and Huffman codes can be found in [14]. For most images, PNG can achieve greater compression than GIF.

3. BACKGROUND OF THE PROPOSED METHOD

In this section, we will first explain our motivation behind the idea of the proposed approach.

A well-known observation in data compression is that: low-frequency smooth signals can be easily compressed while high-frequency ones (signals with a lot of high-frequency components) are not. Therefore, it is highly desirable to convert high-frequency signals into low-frequency ones. This will significantly improve data compression efficiency.

In conventional lossless compression methods, such as GIF [8, 10] and PNG [13, 14], the 2D-image is scanned line by line providing one dimensional signal. In such coder, redundancies in directions others than horizontal one, are omitted [9, 11, 12]. However, redundancy in these directions could be more relevant than horizontal one, and so, scanning the image in suitable direction may provide a smoother signal with lower frequency components.

Figures 1and 2 show the 1D-signal generated after zigzag and horizontal scan of two 8x8-blocks extracted from “lena” image.

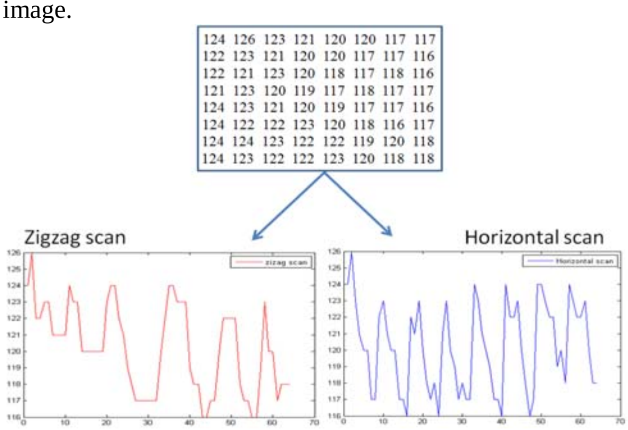

Figure 1. 1D-generated signals by zigzag and horizontal scan, (example 1).

The figure 1 shows that the signal generated from the first block example by zigzag scan is visibly more monotone and smoother than one generated by horizontal scan. This could be confirmed by measured autocorrelation of the two signals as it is shown in figure 2.

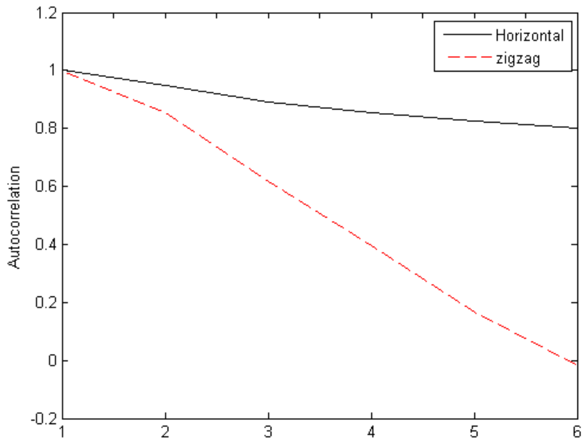

Figure 2. Comparative on autocorrelation between signals generated by horizontal and zigzag scan (example 1)

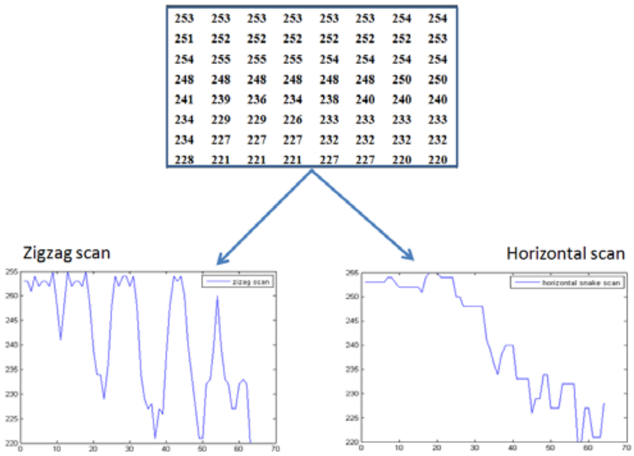

Figure 3. 1D-generated signals by zigzag and horizontal scan, (example 2).

Getting back to the figure 3, the signal generated from the second block example by horizontal scan is visibly more monotone and smoother than one generated by zigzag scan. Such signal must have less high frequency component and then easier to compress.

These examples show that the resulting 1D signal propriety depends on how to scan the 2D source signal: This is could be approved by the two horizontal and zigzag scan generated signals autocorrelation measurements shown in figures 2 and 4.

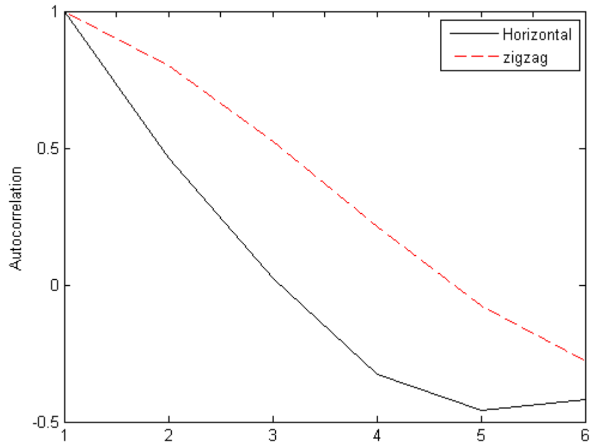

Figure 4. Comparative on autocorrelation between signals generated by horizontal and zigzag scan (example 2)

Thus, our purpose consists in designing a method aiming to find the scan which could generate the smoother signal.

4. PROPOSED METHOD

The proposed approach consists in finding the minimal pixel's change direction in order to select a scan that would generate a high correlated and monotone pixels sequence (signal with minimal fluctuations).

As it is shown in figure 5, the proposed method starts by analyzing the pixels activity in each block of the original image to detect pixels intensity change direction.

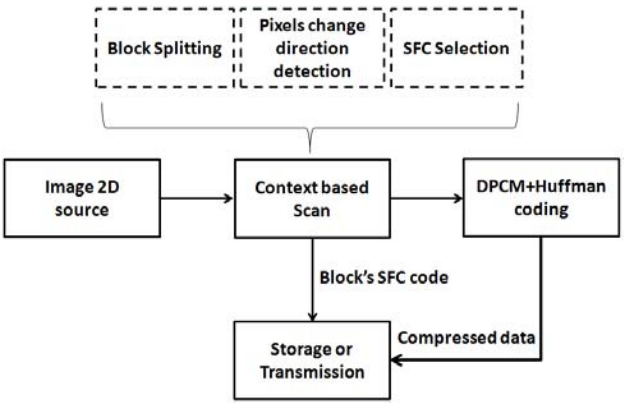

Figure 5. Proposed coding scheme

Subsequently, a decisional algorithm would find the best SFC (Space Filling Curve) that scans the image by promoting the direction in which the pixel values change is minimal. Four SFCs are explored, and each SFC is presented by some code. The signal generated after the proposed scan process should present a strong correlation and minimal fluctuation. This signal is compressed and transmitted with the selected SFCs codes.

In the following, we give detail method description.

4.1. Blocks splitting

The first step consists in splitting the original image into isometric squared blocks. Each bloc has its own local auto-correlation characteristic and nearby pixels similarity, that's why, each block will have its own SFC which should be adapted to pixels block activity. This step aims to exploit the relevant local image autocorrelation.

4.2. Detection of Minimal pixels change direction

Now, the coder computes the pixels variations in the horizontal, vertical, first and second diagonal directions (cf. figure 6). The coder intended primarily to detect the direction in which the considered block pixels tend to vary less. The coder should avoid scanning pixels in the direction where pixels intensity tends to fluctuate.

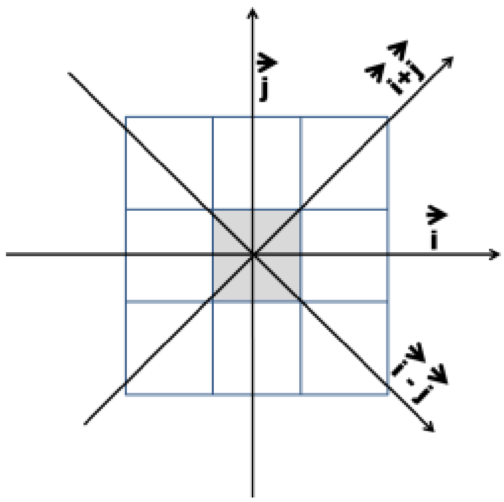

Figure 6. Considered pixels variation directions

To achieve this goal, we designed a simple and effective method that can approximately estimate the pixels variation direction by comparing the pixels by their neighbors:

The first step consists in a sub-sampling process. Thus, each block is represented by four sub blocks as shown in Figure 7.

Subsequently, we try to calculate the horizontal, vertical, first and second diagonal sub-block translation.

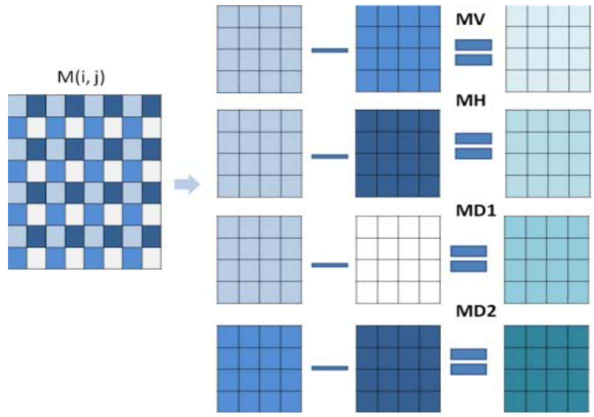

Figure 7. Detection of pixels varaition direction

As shown in Figure 7, the sub-block "MV" represents the vertical variations, "MH" represents the horizontal ones, "MD1" shows the variations in the first diagonal direction and "MD2" represents changes in the second diagonal direction.

Next, we calculate the sum of each sub-block pixels values in order to detect pixels variation direction:

- $SV=\sum_{i=1}^{H/2}\sum_{j=1}^{L/2}[M(2i-1,2j-1)-M(2i,2j-1)]$
- $SH=\sum_{i=1}^{H/2}\sum_{i=1}^{L/2}[M(2i-1,2j-1)-M(2i-1,2j)]$
- $SD1=\sum_{i=1}^{H/2}\sum_{i=1}^{L/2}[M(2i-1,2j-1)-M(2i,2j)]$
- $SD2=\sum_{i=1}^{H/2}\sum_{i=1}^{L/2}[M(2i,2j-1)-M(2i-1,2j)]$

Where

- SV corresponds to the sum of the MV coefficients.
- SH corresponds to the sum of the MV coefficients.
- SD1 corresponds to the sum of the MD1 coefficients
- SD2 corresponds to the sum of the MD2 coefficients
- H (resp. L) corresponds to width (resp. height) of the considered block (M).

4.3. SCAN selection

According to the aforementioned considered directions, the coder chooses between 4 proposed SFC's (cf. figure 8):

- Horizontal snake scan
- Vertical snake scan
- First Zigzag scan
- Second Zigzag scan

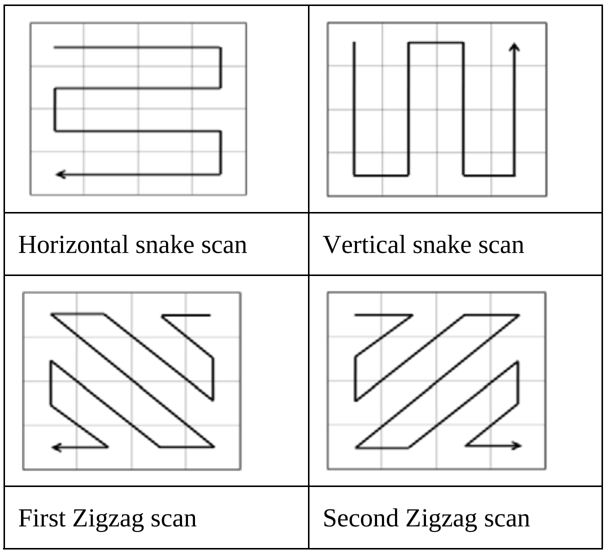

Figure 8. The four used SFC's

For each image bloc, the appropriate scan is selected as follows:

• If min (SH, SV, SD1, SD2) = SH then the minimal pixel's change direction is the horizontal one, consequently the selected SFC will be the horizontal snake scan.

• If min (SH, SV, SD1, SD2) = SV then the minimal pixel's change direction is the vertical one, consequently the selected SFC will be the vertical snake scan.

• If min (SH, SV, SD1, SD2) = SD1 then the minimal pixel's change direction is the first diagonal one, consequently the selected SFC will be the first zigzag scan.

• If min (SH, SV, SD1, SD2) = SD2 then the minimal pixel's change direction is the second diagonal one, consequently the selected SFC will be the second zigzag scan.

In order to check the adopted decisional criteria, we tested our scan selection method justness on 5175 8x8-blocks extracted from 20 images. For each block, we record the scan selected by the proposed method. Next we apply the four considered SFCs. Generated pixels sequences are DPCM and Huffman coded in order to detect the most efficient SFC (the one offering minimal string length) and then we check if it is the same chosen by our method. Among 5175 blocs, the proposed scan process offers 3580 good decisions.

Other similar technique which is based on gradient concept in order to detect minimal pixels change direction is described in [21].

4.4. Coding step

After applying the scanning process, we obtain a pixels sequence representing the block. The penalty of similar SFCs based coding approaches is that the path along which pixels are encoded must be stored. However, in our case, there is no need to explicitly store the entire path as we use standards SFCs.

We only need 2 bits per bloc to code the selected scan:

- 00: horizontal snake scan
- 01: vertical snake scan
- 10: first zigzag scan
- 11: second zigzag scan

The pixels sequence generated by scan process is highly correlated. Such signal is a perfect input for the predictive coder such as DPCM.

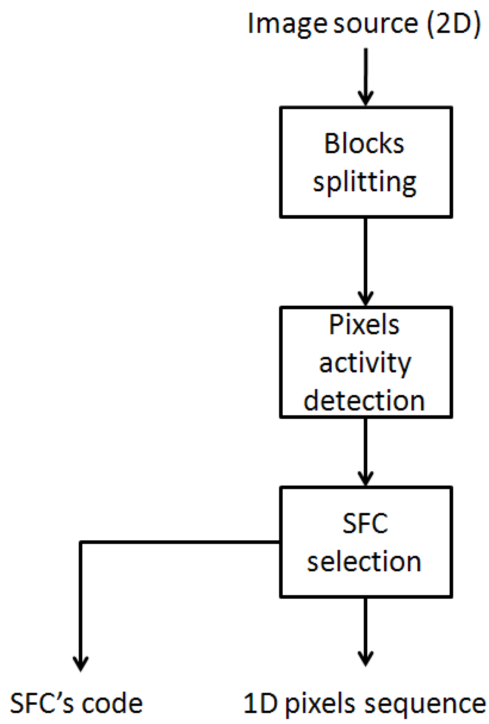

Figure 9. Scan process

A. DPCM

The idea of predictive coding algorithm is to predict, the next coming value based on the values already known. It is based on the statistical dependence between the neighbouring pixels. On the transmitter side, using predictive coding, only the differences (residuum) between the original and predicted values are transmitted.

Generally, pixels in one block have more correlation than ones in the whole image, that's why we apply the DPCM on each pixels sequence separately in order to maintain residuum values as small as possible.

In this work, first level DPCM is used to decorrelate blocks pixels sequence.

B. Huffman coding

In the next step, residuum sequences of all image blocks will be concatenated in order to be Huffman encoded.
Each block has one predictor and a differences sequence. Predictors and residuum sequences will be coded separately. The variation range of these residuum values is small because of the high correlation of the input signal. As a result, the probability of patterns repetition is high which increases the efficiency Huffman coder.

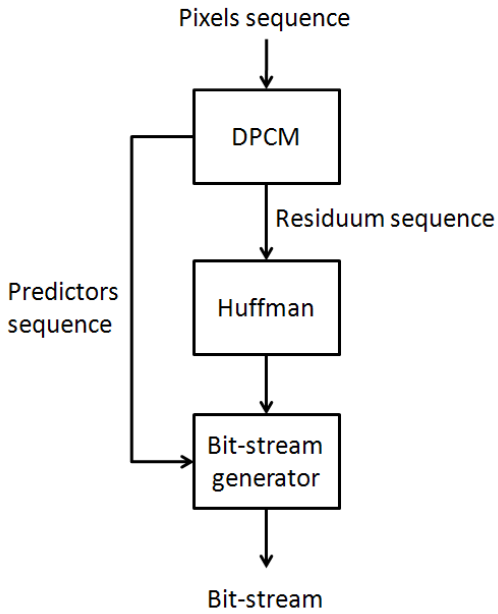

Figure 10. coding process

C. Bit-stream structure

Figure 11 shows the structure of the generated bitstream:
The header includes information about the image (such as resolution) and the Huffman table.
The rest of the bitstream includes information about each block, two bits used to encode the selected scan, then 8 bits for the predictor, followed by the Huffman codes of the residuum sequence.

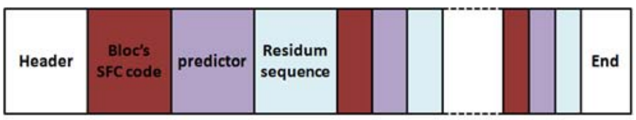

Figure 11. Bit stream structure

5. EXPERIMENTS

The proposed scheme was tested with of different types of images: object, person, face, building, texture etc. (image 12). All images are bitmap images with 256possible gray levels (0-255), stored at 8 bits per pixel.
Table 1 summarizes a comparative study based on the performance of compression between the proposed method and universal lossless coding.

Figure 12. Abstract, Paolina, Building, Man, Goldhil, Pout, Viptripes, lena

As depicted in table 1, the proposed method shows a significant improvement compared to conventional coders.

Table 1. Compression performances evaluation

Bench mark	GIF (bpp)	PNG (bpp)	Proposed method (bpp)
Abstract	7,1	6,5	4.66
Paolina	8,15	7,09	5.05
Building	6,15	5,25	4.92
Goldhil	8,1	7,1	4.97
Pout	6,25	5,65	4.01
Viptripes	7,5	6,5	4.59
Man	7,55	6,45	5.04
Lena	8.6	7.3	5.07

The proposed code outperforms the GIF and PNG standards in all the tested images. It shows an increased compression at the range of 20-38% (resp. 6-30%) over GIF (resp. PNG) standards.
The proposed coder show remarkable compression stability;
As depicted in table 2, the bitrate of compressed images varies, in most cases, around 4 bpp. This stability is reflected by the low variation of compressed image bitrates as it is shown in table 4.

Table 2. Compressed image bitrates variation

	GIF	PNG	Proposed coder
Δbpp	2,45	2,05	1,06

This improvement is principally due to many facts; First of all, the proposed scan takes its advantages from the image local correlation, which is accentuated in the block by block adopted scan method.

Second, high frequency component, which is hard to compress, is reduced by the "intelligent scan" that tends to follow the direction where minimal pixel's intensity change is recorded.

Third, the proposed method has insignificant additional data for the further image reconstruction unlike other state of the art approaches which require considerable additional date to code the non standard scan path [5-7].

6. CONCLUSION

In this paper a new lossless image compression method is presented. The proposed method tries to explore redundancies in different directions unlike conventional coding schemes that utilize horizontal scan direction. Such strategy explores psychovisaul redundancy largely ignored by many state-of-the-art coders. By reducing high frequency components of the original signal, the method transforms subjective redundancy hard to process into other exploitable redundancy. Using a limited number of standards scan curve minimize considerably the additional data -necessary for image retrieval- cost, unlike other similar works [7, 9] which require considerable additional date to code the non standard adopted scan trajectory.

Relying on standards concepts (DPCM, Huffman) make it easy to implement and to integrate in any applications. In addition, the presented coder presents low computational processing with possibility of parallel HW/SW implementation. The compression efficiency improvement brought by the proposed method make the SFC exploitation in image compression an ambitious future direction of our research. In this context, we work on other more efficient scan methods.

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