Lossless Binary Image Coding Using Hybrid Coding Method

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Abstract—Lossless image coding is a very important technique to efficiently and perfectly reducing image storage and having many application fields such as: medical images, seismic data, digital archives and digital documentations. In this paper, we present a new approach of a lossless binary image coding which combines two coding process. The first one is based a neighbourhood code reduction which transforms binary image into a proper mapping representation. The second one uses arithmetic coding which produces bitstream with a good compression ratio. The performance of the algorithm is tested on different binary images that contain Arabic letters and compared to some algorithms such as LZW and CCITT Group 4.

I. INTRODUCTION

The goal of image coding is to reduce, as much as possible, the large number of bits necessary to represent and reconstruct a faithful duplicate of the original picture. However, several methods were suggested and used in a variety of application to code these images, like CCITT Standards Group 4 used in facsimile communication and JBIG in digital printing. The objective of a lossless image compression technique is to allow the exact original data to be reconstructed from the compressed data [1][2].

There are several methods for encoding an image, but can be grouped into three categories: The canonical coding methods, the statistical coding methods and the dictionary-based coding methods.

The canonical coding methods use the structural properties of images to be coded. To extract these properties, image is scanned sequentially and each pixel is examined. A decision concerning that pixel is made. In the decoding procedure we need the protocol in the encoding module. The main canonical method is the Run-Length Coding (RLC). This method replaces the consecutive sequences of symbols by a code composed by the number of occurrences followed by the value of the pixels forming the sequence (run, value). The drawback of this method is its efficiency only for messages having a large number of repeated symbols. This method is used by the BMP, TIFF and PCX coding. The statistical coding methods define a variable code for each symbol, depending on statistical criteria. The encoding process affects the shortest code to the probable symbol and the longer code to the other symbol. So it is necessary to pre-analysis the message to determine the occurrences of symbols and to insert the coding alphabet in the encoded message. Huffman code is one of the most known methods in this category. This algorithm identifies symbols and their probability distribution; and constructs the binary tree by sorting the symbols according to their probability it’s followed by the creation of a new node with the two symbols assuming the smallest probability and so on.

The dictionary-based coding methods are based on the analysis of repeated words in the processed message. Its principle is to build a coding table called dictionary which stores the repeated words in a dictionary and then replaces these words by their index in the dictionary (indexing step). So these methods assign a fixed-length index to a variable length symbol. To decode message it needs dictionary used in coding process. The Lempel-Ziv LZW is one of the most known methods in this family.

The main contribution of this paper is to present a binary image coding technique based on a neighbourhood coding with reduction that offer an ideal image representation followed by arithmetic coding that achieves a higher compression ratio.

This paper is organized as follows: In the next section, we present and discuss the proposed method. Experimental results are described in section 2. Finally, conclusion and future works are presented in Section 3.

II. PROPOSED METHOD

Our proposed method is based on a hybrid lossless binary image coding including canonical (Neighbourhood coding) and statistical (arithmetic coding) methods. As shown in Fig.1, the proposed method named "NCRAC" consists of three principal functional modules: Neighbourhood Coding; code Reduction and Arithmetic Coding.

In the next sub-sections, we explain these principle modules in more details.

A. The neighbourhood coding

The neighborhood coding procedure transforms the image into a set of neighborhood codes that represent each pixel of...
Several approaches have been proposed to encode binary images. Among these methods, the Tsang and al [3] algorithm which characterizes objects in a binary image by converting every foreground pixel into a vector $V_i = (n_i, e_i, s_i, w_i)$ (empty at the beginning) (Fig.2). This matrix builds the whole objects. As we see this method transforms an $n \times m$ pixel image into $p \times 6$ elements.

So we need to identify the pixels belonging to the foreground (i.e. pixels that have values equal to 1). Then we scan the image sequentially from top-left to down-right and each time we locate a foreground’s pixel $i$, we calculate their neighbourhood vector $V_i$. The set of all vectors produce a $\phi$ matrix where $\phi_i = (x_i, y_i, n_i, e_i, s_i, w_i)$ (Fig.3). This matrix builds the whole objects. As we see this method transforms an $n \times m$ pixel image into $p \times 6$ elements.

This representation contains many redundancies because the information contained in one code can be coded in another code. So we need a code reduction process.

**B. Code reduction**

The code reduction method aims to obtain the least number of neighborhood vector codes necessary to represent the whole image without loss of information [4]. The idea is to create a column vector $CC$ representing the coding capacity of each element $V_i$ defined as:

$$CC_i = \sum V_i \text{components}$$

(1)

Then we choose the code with maximum capacity and identify the pixels that were associated with this code. Next we update the coding capacity by subtracting the number of pixels will not be coded anymore (Fig.4).

Fig.5 presents an update coding capacity example applied on a simple image. The number in box represents the coding capacity for the corresponding pixel [4]. In the first step (Fig.5 (a)), pixel $(x_i = 4, y_i = 3)$ has maximum capacity code 13, so it will be marked as coded. His neighbourhood is formed by grey pixels that will not be...
coded anymore. Then, in this step pixel \((x_i = 5, y_i = 2)\) has a capacity code equal to 12 and has two neighbourhood pixels \((x_i = 4, y_i = 2)\) and \((x_i = 5, y_i = 3)\) that have been already coded. So, in the next step, their capacity code will be updated by subtracting 2 to give 10 (Fig.5 (b)).

C. The arithmetic coding

Arithmetic coding is the step generating the binary bit-stream. This algorithm is a form of entropy coding which overcomes the drawback of the Huffman coding [6]. The basis of this algorithm is to represent a sequence of \(n\) symbols as a number between 0 and 1. It is based on iterative division of an interval to the sub-intervals proportional to the symbol’s probability distribution (Fig.6).

D. Decoding of the encoded data

The decoding is the opposite process of the encoding which follows the outlined steps in Fig.7.

From the binary file as input, arithmetic decoding is applied. This consists of entering the symbols and their ranges while reconstructing their frequencies and probabilities [2]. From this stage, we obtain two output parameters: the size (i.e. size height and weight) of the image (to be reconstructed) and the \(\Phi\) matrix. From the size, we reconstruct a black image and from the \(\Phi\) matrix, we reconstruct the objects located on this image by treating each \(\phi\) sequentially in four directions of neighborhood pixels.

III. EXPERIMENTAL RESULTS

To test the performance of the algorithm, we use binary images samples that contain Arabic letters as shown in Fig.8. Table 1 shows the image dimensions (width x height), the total number of codes required before and after reduction.
According to these results, we note that the number of representative pixels was reduced approximately to 4.5%. In the next experiments, we compare the performance of the algorithm with some image coding algorithms such as LZW used in the GIF file format and CCITT group 4 used in the TIFF file format. The compared criterion uses the compression gain defined by:

\[ CG = 1 - \frac{\text{size of the input file}}{\text{size of the output file}} \]  

According to the results of Fig. 9, we note that our method has the better compression gain.

**IV. CONCLUSION**

In this paper, we have presented an hybrid approach of lossless binary images compression based on Neighbourhood Coding with reduction using Arithmetic Coding. The basic idea is to decrease, as much as possible, the number of pixels that represent the whole image and to generate the bitstream to be archived or transmitted. According to experimental results, the proposed method is very promising compared to the other methods. Future works involve testing and developing approach on more complex documents.

**REFERENCES**


