Fast Near-Lossless Image Compression with Tree Coding Having Predictable Output Compression Size

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Abstract. Image compression, in the present context of heavy network traffic, is going through major research and development. Traditional entropy coding techniques, for their high computational cost is becoming inappropriate. In this paper a novel near-lossless image compression algorithm had been proposed which follows simple tree encoding and prediction method for image encoding. The prediction technique uses a simple summation process to retrieve image data from residual samples. The algorithm had been tested on several gray-scale standard test images, both continuous and discreet tone, and had produced compression comparable to other state-of-the-art compression algorithms. The output compressed file sizes had shown that they are independent of image data, and depends only on the resolution of the image, an unique property that can exploited for networking bandwidth utilization.

Keywords: Modelling – coding architecture, median filtering, residual samples, tree encoding, progressive transmission.

1 Introduction

Image compression researches are conducted to optimize storage space requirements for efficiency in storage and data-transfer over networks [1]. The lossless concept of image compression [2] although produces errorless output, cannot provide excellent compression. The lossy concept exploits the fact that human cognition is unable to detect very small intensity variation in small areas of an image. Although this concept provides excellent compression but sometimes loss of image information becomes unacceptable, for instance in medical image processing or image archival where machine based image processing is involved.

Recently, the research interest in this field had been diverted to development of near-lossless compression methods. Algorithms like LOCO-1[5], JPEG-LS[3], JBIG[4] and FELICS[7] have been developed on this concept. All these algorithms follow the *modeling-coding* architecture.

Firstly, image data was modeled using prediction algorithm like DCT[8] or DWT[9] and the deviation of predicted value from actual, called residual sample, was stored. Then the residual samples were encoded using entropy encoding techniques like Adaptive Huffman, Hierarchical Interpolation or Tree encoding[6]. These

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approaches involved intensive computation due to the statistical data manipulation and encoding techniques employed by them. Each of the standards provides a faster version, which results in a trade-off in compression quality.

In this paper a new compression technique for gray-scale images had been proposed. The technique involves three basic steps: 1) *image smoothening* 2) *tree encoding* of the image information and 3) *representing intensity of tree using ASCII character* set for optimized storage requirement. The computational cost was low since only linear search and subtraction operation was involved in image modeling part. The simulated results on standard test images had given comparable or better compression ratio than the standard algorithms.

The remaining paper had been organized as follows: section 2 discusses the detailed algorithm, section 3 presents the simulation results and in section 4, the paper is concluded.

2 Proposed Algorithm

2.1 Image Compression

The proposed algorithm complied with the *modeling–coding* architecture. The image had been smoothened to emphasize intensity correlation (section 2.1.1). The image modeling part had been done using residual calculation from maximum intensity in blocks of the image (section 2.1.2). The encoding of thus produced residual samples had been done using tree encoding (section 2.1.2). Consequently, data representation completed the process (section 2.1.3).

2.1.1 Image Smoothening

The image had been smoothened using median filtering on 2X2 masks throughout the image. This step ensured that the truncation of the image tree did not result in drastic loss of image information since median filtering emphasized on statistical correlation among pixels.

2.1.2 Modeling and Progressive Encoding of Image Data

The smoothened image had been encoded in a tree architecture using 4 children (one block) at each level for next level node determination. In the proposed method, consecutive blocks are selected and according to the following steps the image was encoded:-

1. Calculate the maximum intensity value in the selected block.
2. Subtract all other intensities in the block from this value.
3. The last intensity will be involved in further tree encoding at the next level, hence it is not stored at the current loop of execution.
4. The remaining three are stored using character representation (section 2.1.3).

The conceptual idea behind the encoding technique is explained in figure1.

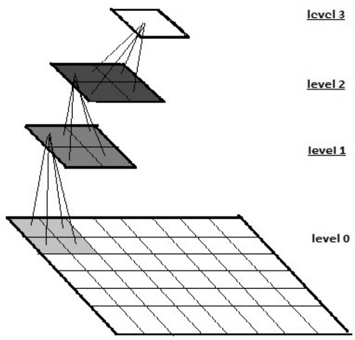

Fig. 1.

As shown in the figure, at each level the resolution of the image gets halved. The resultant tree (expanded to 2 levels) for a 256X256 image is shown in fig 2.

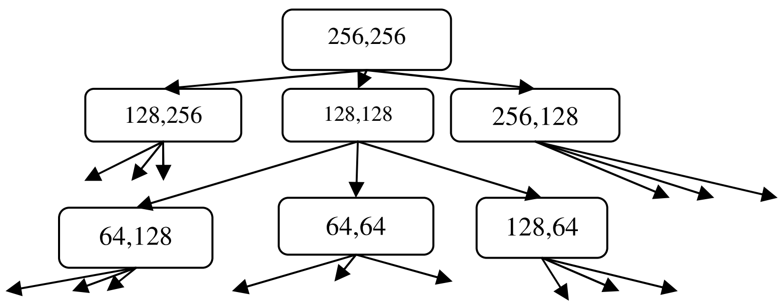

Fig. 2.

2.1.3 Residual Sample Coding

The maximum intensity, in each block, had been selected for quantization (refer to 2.1.2). Hence, residual samples were in the range of [0 – 255] since only 8 bit images have considered. 8 bit ASCII character set defines 255 character symbol set. Of these, three symbols were found unfit for the purpose of intensity representation. ASCII symbols, corresponding to each intensity value, had been used in the sample encoding. The last three intensities had been assigned 2-character hybrid symbols. Also the subtraction for the local maximum intensity ensures that no negative value appears, which otherwise would have to be represented using symbols thereby reducing the resultant compression ratio.

Alternate Strategies for Achieving Greater Compression

The image tree formed can be truncated at several levels. Default strategy was to truncate the tree at level 0 because of high correlation of intensity values in 2X2 masking window. This concept was extended to level 1 tree truncation, which resulted in a smoothened image with 4X4 masking. The second approach, although notably increased the compression ratio, resulted in comparatively higher error of deviation (refer section 3, table 1 and 2).

2.2 Image Decompression

The decompression of the compressed file was done following steps discussed below:

1. Generated the symbol table as discussed in section 2.1.3.
2. Read symbols from compressed file and found the corresponding intensity values. Hence the image tree was remade.
3. Found the maximum in a parent-children block and subtract other values from the maximum value to regenerate original image matrix.
4. Use the last level leaf node values to regenerate the entire image matrix, which is the median filtered (2X2 masking) output of the original image.

3 Simulation Results

Some definitions that were used to study and compare results with other techniques:

$$\text{Bits/Pixel (BPP)} = (8 \text{ X Compressed File Size})/(\text{Actual File Size}) \quad (1)$$

$$\text{RMSE} = \sqrt{\frac{1}{row*col}\left[\sum_{i=0}^{row}\sum_{j=0}^{col}\left\{f(i,j) - \hat{f}(i,j)\right\}^2\right]} \quad (2)$$

The algorithm had been applied on standard gray-scale test images, both continuous-tone and discreet-tone types. The compression percentage achieved had varied from 96-98% for different test images. The test images were shown in figure 3.

Fig. 3. The test image set: (from left to right) lena(512X512); mandrill (256X256); discreet (64X64); peppers(256X256); nasa(512X512); jet (128X128)

The error in output generated had been shown in table 2. The scale of reference was Root Mean Square Error (RMSE), as defined above. The tabulation was done for RMSE values acquired for level 0 and level 1 image tree truncation (refer to fig1).

The experimental results suggested that the output size was predictable. For a 512X512 8bpp image, the output size was 48KB exact in each instance for level 0 truncation of image tree. For level1 truncation the size was 12.0 KB, although this

Table 1. The comparative study of detailed results of the compression output in BPP of the proposed algorithm, with level 0(L0) and level 1(L1) truncation with JPEG 2000

Image name	Lena	Mandrill	Peppers	Nasa	Discreet	Jet
JPEG 2000	0.46	0.68	0.41	0.28	0.56	0.12
PROPOSED (L0)	0.39	0.42	0.39	0.24	0.48	0.38
PROPOSED (L1)	0.09	0.13	0.10	0.11	0.05	0.09

Table 2. The RMSE result for level 0(L0) and level 1(L1) truncation of the original image tree

Image	Lena	Mandrill	Peppers	discreet	Nasa	Jet
RMSE (L 0)	15.35	12.33	17.36	25.09	5.54	6.46
RMSE (L 1)	20.24	17.35	21.54	29.09	7.82	10.98

increased the error level, as discussed in table 2. The predictability of the output image size could be used as a great advantage for network utilization by helping in pre-planning resource allocation.

4 Conclusion

In this paper a new approach of compressing image had been presented using the *modelling-coding* architecture. The computation time was comparatively much lower than the standard algorithms, which involved complex algorithm (DCT approach in JPEG, DPCM in CALIC) for image modelling. The results showed encouraging compression ratio and information loss was also within moderate range even for level 1 truncation strategy of the proposed method. The algorithm ensured fast encoding, predictive output result and simple progressive transmission based decoding which made it suitable for network data-transfer or fabrication on mobile devices.

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