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A Novel Video Compression Scheme Based on Fast Curvelet Transform

Ahmed M. Elmolla[1], Gouda I. Salama[2] and Ashraf D. Elbayoumy[3]

[1,2,3]The Egyptian Armed Forces, Cairo, Egypt-11331

***Abstract*– This paper describes a method for video compression using a new technique: combining fast curvelet transform with both run length and Huffman encoding. By adjust the number of element in each matrix in the output of fast curvelet transform then applying Run length and Huffman encoding. Run length codec is suited for compressing any type of data regardless of its information content. Huffman coding the principle is to use a lower number of bits to encode the data that occurs more frequently. This technique works fairly well for grayscale as well as color videos.**

***Index Terms*– Video Compression, Curvelet Transform, Run Length Codec, Huffman Coding, SSIM and PSNR**

I. INTRODUCTION

THE extensive use of multimedia technology over the past decades has increased the demand for digital information. This awful demand made the current technology inefficient in handling the huge amount of data [1]. Video compression by eradicating the redundancies present in it removes this problem. Generally, the video compression technique comprises of three techniques namely, transform, and two encoding. The fundamental goal of data compression is to reduce the bit rate for transmission and storage of the information while maintaining the video quality.

Combining fast Curvelet transforms and run length codec in addition to Huffman coding will be representing in this paper. The curvelet transform technique was originally introduced by Candes and Donoho in 1999 as a result of the increasing demand of the presence of effective multi-resolution analysis that has the ability to overcome the drawbacks of wavelet analysis [2]. The transform was designed to represent edges and other singularities along curves much more efficiently than traditional transforms.

The fast curvelet transform coefficient will be coded by run length coding to compressed many consecutive data elements and stored as a single data value and count, rather than as the original run. The count output of the RLC will be encoding by Huffman coded and stored in a Code Book which may be constructed for each video frame. The code book plus encoded data must be transmitted to enable decoding.

In order to measure the extent of compression parameters like Compression Ratio, Peak Signal to Noise Ratio (PSNR) and Structural Similarity (SSIM) are used.

II. TRANSFORM AND CODING FOR COMPRESSION

A) Curvelet Transform

Curvelet transform developed by Candes and Donoho is a new multi-scale transform designed to represent edges and other singularities along curves much more efficiently than the traditional transforms.

The curvelet transform, is a multi-scale transform, with frame elements indexed by scale and location parameters. It has directional parameters, and the curvelet pyramid contains elements with a very high degree of directional characteristics. The curvelet transform is based on a certain anisotropic scaling principle. The elements obey a special scaling law, where the length of the support of frame elements and width of support is linked by the relation:

$$Width \approx Length*2$$

Fast curvelet Transform coefficient matrixes depend on number of scale, which can affect the video quality if using incorrect number of scale. The higher CR with a higher video quality need an acceptable number of scale (S) which depend on the video frame size can calculated by [3]:

$$S = \log_2 nim(M, N) - 3 \qquad (1)$$

Where,

S is number of scales

M, N number of Video Frame pixel

B) Run length encoding (RLE)

Run length encoding (RLE) is perhaps the simplest compression technique in common use [4]. RLE algorithms are lossless, and work by searching for runs of bits, bytes, or pixels of the same value, and encoding the length and value of the run. As such, RLE achieves best results with images containing large areas of contiguous color, and especially monochrome images. Complex color images, such as photographs, do not compress well – in some cases, RLE can actually increase the file size. There is a number of RLE variants in common use, which are encountered in the TIFF, PCX and BMP graphics formats.

C) Huffman coding

Huffman coding is algorithm for lossless data compression it is desirable for a code to have the prefix-free property, for any two symbols, the code of one symbol should not be a prefix of the code of the other symbol [1]. Huffman's algorithm is a greedy approach to generating optimal prefix-free binary codes. Optimality refers to the property that no other prefix code uses fewer bits per symbol, on average, than the code constructed by Huffman's algorithm.

Huffman's algorithm is based on the idea that a variable length code should use the shortest code words for the most likely symbols and the longest code words for the least likely symbols. In this way, the average code length will be reduced. The algorithm assigns code words to symbols by constructing a binary coding tree. Each symbol of the alphabet is a leaf of the coding tree. The code of a given symbol corresponds to the unique path from the root to that leaf, with 0 or 1 added to the code for each edge along the path depending on whether the left or right child of a given node occurs next along the path.

III. OBJECTIVE

The objective of this work is to compress the data in the video frames using Curvelet transform along with Run length and Huffman Encoding techniques. The B/W video sequence is used for compression. The basic steps of the proposed new technique based compression algorithm are shown in Fig. 1. Initially video is fed into MATLAB which will be converted to numbers of video frames then appling Fast Curvelet Transform to get the output matrixes coefficient with its rows and columns same as the pixel values of the image. The Fast curvelet coefficient preprocessing is apply to arrange the coefficient to be the input for the Run length encoding then applying Huffman Coding to the output of RLE the final output image will be compressed. In the future this can also be implemented for compression of surgical videos and medical images.

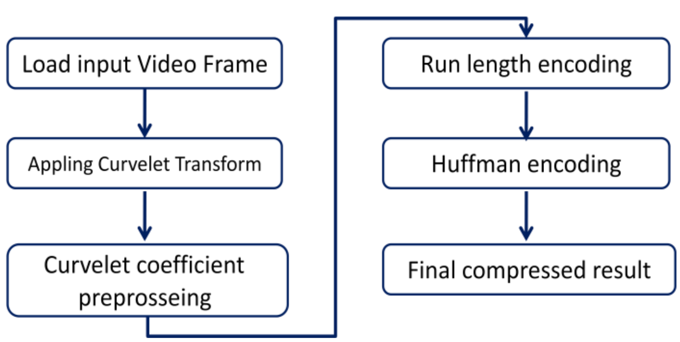

Fig. 1: Flow Diagram of Compression Process

IV. METHODOLOGY

The basic steps of the proposed new technique based image compression algorithm are shown in Fig. 2.

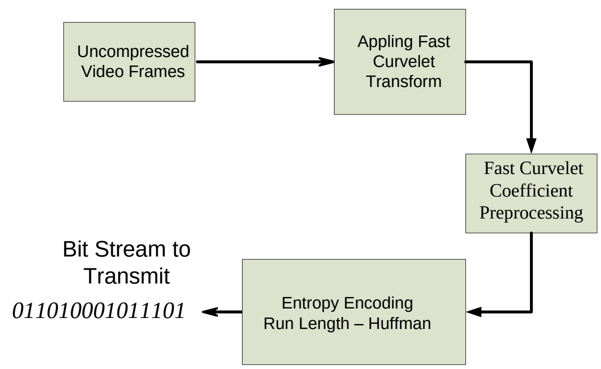

Fig. 2: Proposed encoding video compression scheme

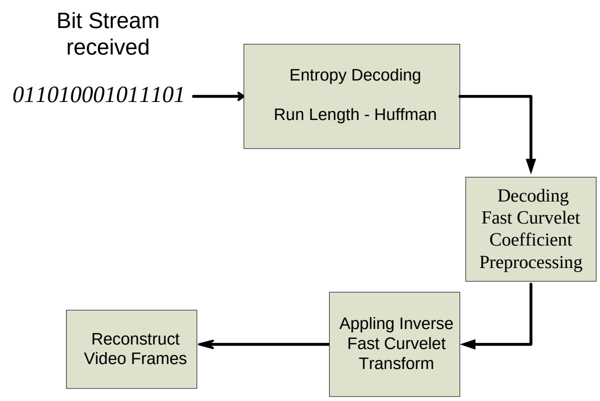

Fig. 3: Proposed decoding video compression scheme

A) Performance Parameters

The objective video quality metrics like Compression Ratio, Peak Signal to Noise Ratio (PSNR) and Structural Similarity (SSIM) are used for the evaluation of this approach. Compression ratio is used to enumerate the minimization in image representation size produced by an image compression algorithm. The data compression ratio is equivalent to the physical compression ratio used to evaluate physical compression of substances and is defined as the ratio between uncompressed video frame size and compressed video frame size:

$$compression\ ratio = \frac{uncompressed\ frame\ size}{compressed\ frame\ size} \quad (2)$$

MSE is computed by averaging the squared intensity difference of reconstructed image, original image. Then from it MSE is calculated as:

$$MSE = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left|\hat{f}(x,y) - f(x,y)\right|^2 \quad (3)$$

Where f(x , y) is the original image, f^(x , y) is the decompressed image and M,N are the dimensions of images. Then the PSNR is defined as:

$$PSNR = 10\log_{10}\left(\frac{L^2}{MSE}\right) \quad (4)$$

$$PSNR = 10\log_{10}\left(\frac{L^2}{\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left|\hat{f}(x,y) - f(x,y)\right|^2}\right) \quad (5)$$

Where, $L = 2^B - 1$
B is the number of bits to represent a pixel

Structural Similarity (SSIM) marks a departure from the usual error-sensitivity related approaches in the field of objective video quality measurement [5]. It redefines the approach by designing a metric to capture structural distortion as a measure of perceived image distortion. It is modeled on the human visual system (HVS) perception model. The HVS is specially adapted to extracting structural information from the viewing.

The SSIM index is calculated between two image patches extracted from the same spatial location from the reference R and distorted I image as a function of a luminance comparison term l, contrast comparison term c, and structure comparison term s, as:

$$SSIM\,[R,I] = I[R(t,x,y),I(t,x,y)]\,c[R(t,x,y),I(t,x,y)]\,s[R(t,x,y),I(t,x,y)] \quad (6)$$

Where luminance comparison term *l* is given by:

$$I[R(t,x,y),I(t,x,y)] = \frac{2\mu_{R(t,x,y)}\mu_{I(t,x,y)} + C_1}{\mu^2_{R(t,x,y)} + \mu^2_{I(t,x,y)} + C_1} \quad (7)$$

And contrast comparison term c is given by:

$$C[R(t,x,y),I(t,x,y)] = \frac{2\sigma_{R(t,x,y)}\sigma_{I(t,x,y)} + C_2}{\sigma^2_{R(t,x,y)} + \sigma^2_{I(t,x,y)} + C_2} \quad (8)$$

And structure comparison term s is given by:

$$S[R(t,x,y),I(t,x,y)] = \frac{\sigma_{R(t,x,y)} + C_3}{\text{cov}_{R(t,x,y)I(t,x,y)} + C_3} \quad (9)$$

V. RESULTS

The calculated PSNR usually adopts a dB value for quality judgment, the larger PSNR is, the higher the image quality (which means there is a little difference between cover image and decompressed image). On the contrary smaller dB value means there is a more distortion. PSNR values falling below 30dB indicate fairly a low quality [6].

Compression ratio is used to enumerate the minimization in video frame representation size produced by video compression algorithm [6].

The structural similarity metrics take values from in the range from 0.0 to 1.0, where zero corresponds to a loss of all structural similarity and one corresponds to having an exact copy of the original image [7].

Fig. 3: First frame in each video sequence

Using real video sequence Fig. 3, First video sequence is a stopwatch that has only the second digit is change and has an uniform background, second video s a traffic road with object moving in average speed 60 km/h, third video is an Aquarium with moving object in addition to moving camera which mean the object and background is moved and the last video is Parade kids that's has a moving big object with small uniform back ground.

The result of apply the video compression scheme in the four video sequences shown in Table 1:

Table 1: The result of apply the video compression scheme

Video sequence	APSNR	SSIM	CR
stopwatch	32.632	0.957	25.82
Traffic Road	31.08	0.945	25.11
Aquarium	30.64	0.939	24.93
Parade kids	31.25	0.949	25.6

VI. CONCLUSION

The video compression has become one of the active areas in the field of image processing. This paper has proposed an video compression algorithm which uses a new technique which includes curvelet transform with both run length and Huffman encoding. The compression ratio, PSNR and SSIM have improved to a significant value after the application of the proposed technique.

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