Design and Performance Evaluation of Novel DCT Frame Based Compression Algorithm for Wireless Video Surveillance Systems

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Abstract— Closed Circuit Television (CCTV) is one of the most important and commonly used security systems for business, home and public safety. Surveillance video data from these CCTV cameras allow us to monitor assets from any illicit and uncalled activities. Further, wireless CCTV surveillance systems are gaining popularity because of remote surveillance, rapid deployment, scalability, reduced cost etc. However, due to restricted bandwidth resource in wireless technology, CCTV video output should be compressed in order to fit into the available bandwidth with reduced complexity and cost. Hence in this paper, a new novel DCT frame based video compression algorithm is formulated which reduces the number of computational steps during video compression by eliminating quantization, zigzag scanning and run length encoding. The performance of proposed algorithm is evaluated using MATLAB by considering Compression Ratio, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) as performance metrics.

Keywords— *DCT, Video Compression, CR, MSE, PSNR*

I. INTRODUCTION

Video Surveillance is increasing penetrated in all most all the fields of society from ensuring security at airports, banks, and correctional institutions. More recently, government agencies, corporate business, educational institutions, etc are using video surveillance to enhance the public security, law enforcement, remote monitor crime and reduce violence [1]. Further, in advanced wireless network technology, networked video surveillance have become a powerful solution to overcome challenges such as distance, lack of network infrastructure, severe conditions, cost etc [2] due to its reduced cost, rapid deployment, scalability and rapid installation without relying upon a the fixed infrastructure [3]. However due to limited bandwidth in wireless technology, the video data output of surveillance cameras need to be compressed in order to fit into the available bandwidth [4]. Currently video compression algorithms are focused on only reducing the bandwidth without considering complexity and cost. Hence in this paper, a new novel DCT frame based video compression algorithm is formulated to reduce complexity and cost. The performance of the proposed algorithm is evaluated using MATLAB by considering Compression Ratio, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are performance metrics.

The rest of the paper is organized as follows. Section II gives a brief overview of video compression. In section III, DCT frame based compression algorithm is discussed. Section IV, gives a brief explanation of Performance Metric. Section V outlines the results and discussion, Section VI concludes the paper.

II. OVER VIEW OF VIDEO COMPRESSION

In general video data can be compressed by using either Temporal or Spatial compression techniques. In temporal compression scheme, the MPEG compression technique can be applied for storing the changes between subsequent frames rather than the entire frame.[5] Fig 1 illustrates five frames in MPEG Video sequence.

In Spatial technique, each frame is considered independently. The most common method used in spatial or frame based compression technique is Joint Photographic Experts Group (JPEG). Fig 2 shows an illustration of five frames JPEG compressed video [6].

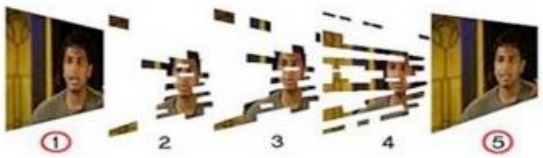


Fig 1. Five frames MPEG video sequence

Fig 2. Five frames JPEG video Sequence

Video compression using spatial algorithm is carried out by applying transforms such as Discrete Cosine Transform (DCT), Discrete Wavelets Transform (DWT), etc., to a single frame. In DCT based spatial algorithms, image can be

reconstructed with fewer coefficients leading to more compression with low complexity [7].

III. DCT FRAME BASE COMPRESSION ALGORITHM

The flow diagram of DCT frame based compression and decompression algorithms are shown in Fig 3 and 4 respectively. During the compression, each frame is scaled down from 8-bit resolution to a 4-bit resolution by considering upper nibble of each pixel by right shifting by four times. Then, the same frame is divided into 8x8 blocks and transformed into frequency domain using Discrete Cosine Transform. In the transform domain, only low frequency coefficients are considered and extracted. In this work, 3x3, 4x4, 5x5 coefficients are considered from top left corner of the each transformed matrix [8] and the rest are discarded. The extracted coefficient values lie within the range of short integer size. Hence, no quantization operation is required and directly converted into one dimensional array starting from first row elements. Since, the collected coefficient is already in one dimension array and does not require Zigzag scanning and run length encodings process. After compression of each frame, the frame sequence number, time stamp and end of frame (EOF) character is concatenated to data array and stored (MATLAB structure).

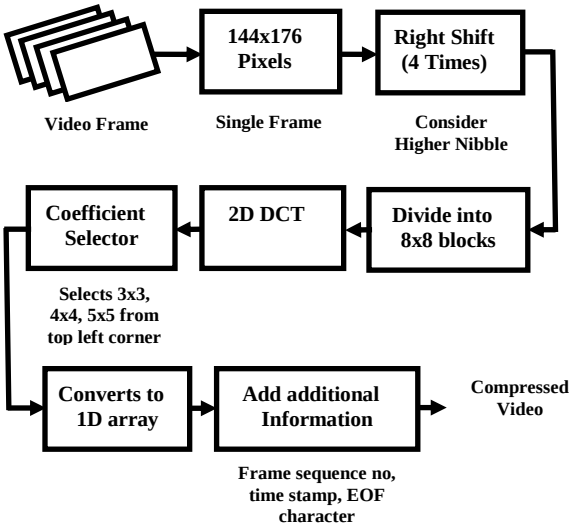


Fig 3. DCT frame based Video Compression flow Diagram

In decompression process, each frame is retrieved using end of frame character. Data and frame information is separated. Later, single dimension array elements are arranged in the form of square matrix as followed in compression method. The zeros are then appended to the extract coefficient matrix to form 8x8 matrices. The resultant matrix is then transformed into time domain and is concatenated suitably to form complete frame. Finally, the data in each frame are right shifted by four times to get back the 8 bit intensity on which frame sequence number and time stamps are printed. Stepwise decompression process is shown in flow diagram in Fig 4.

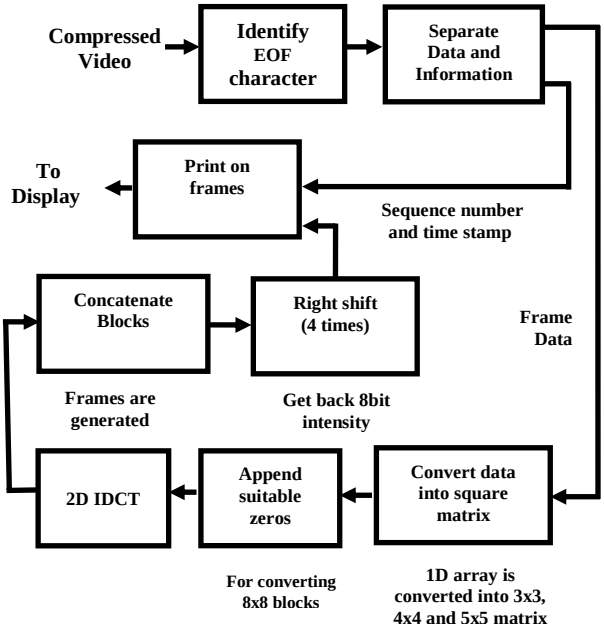


Fig 4. DCT frame based Video Decompression flow Diagram

IV. PERFORMANCE METRICS

Performance metrics considered for evaluating the performance of the proposed DCT frame based compression algorithm are discussed below.

Compression Ratio (Cr) is defined as the ratio of number of bytes in uncompressed frame (n1) to number of bytes in the compressed frames (n2) [9], which is defined in (1)

$$Cr = \frac{n1}{n2} \tag{1}$$

Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR)[10] evaluate the performance of the video compression by estimating the difference between the original frame and the decoded frame. MSE and PSNR are defined in (2) and (3) respectively

$$\text{MSE}=\sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}(f(x,y)-f'(x,y))^2}{WH}} \tag{2}$$

$$\text{PSNR}=20\ \log_{10}\frac{255}{MSE} \tag{3}$$

Where f(x,y) is the pixel values of original frame and f '(x,y) is the pixel values of decompressed frame. W and H are height and width (no of pixels) of given frames respectively.

V. RESULTS AND DISCUSSIONS

DCT frame based video compression algorithm is formulated and evaluated using MATLAB 7 by considering three QCIF resolution (144x176 pixels, 10fps) videos as input. Initially DCT frame based compression algorithm is applied on input video 1 by considering 9 (3x3) low frequency coefficient for compression and decompression. The Performance Metrics such as Compression Ratio, Mean Square Error and Peak Signal to Noise Ratio are calculated using equations (1) (2) and (3) and the values are tabulated as in Table 1, Table 2 and Table 3 respectively. The similar procedure is followed for Video 2 and Video 3. Further, the same procedure is repeated for DCT coefficients of 16 and 25 with all three different videos.

From the Table 1, it is observed that with the increasing number of DCT co-efficient, compression ratios decreases. Also, from the Table 1 it is clear that Cr values are constant for all the three videos for a given number of coefficient. From Table 2 and 3, it is evident that MSE decreases and PSNR increases with the increase in number of DCT coefficient. Original QCIF video frame and reconstructions frames are shown in Fig 5. for different number of DCT coefficients

TABLE I. FOR DIFFERENT NUMBER OF DCT COEFFICIENTS

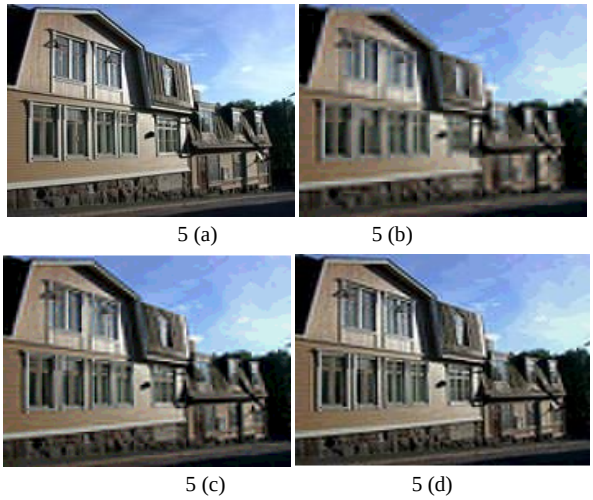
No of Coefficients	Compression Ratio		
	Video1	***Video2***	***Video3***
9	7.111	7.111	7.111
16	4	4	4
25	2.56	2.56	2.56

TABLE II. MSE FOR DIFFERENT NUMBER OF DCT COEFFICIENTS

No of Coefficients	MSE		
	Video1	***Video2***	***Video3***
9	90.75	108.00	102.00
16	85.38	89.10	87.30
25	84.29	84.20	83.80

TABLE III. PSNR FOR DIFFERENT NUMBER OF DCT COEFFICIENTS

No of Coefficients	PSNR		
	Video1	***Video2***	***Video3***
9	28.58	27.84	26.42
16	28.85	28.66	28.06
25	28.90	28.91	28.75



5 (a) 5 (b)

5 (c) 5 (d)

Fig 5. video frames of (a) Input QCIF video, reconstructed video with (b) 9 coefficients, (c) 16 coefficients, (d) 25 coefficients

VI. CONCLUSION

In DCT frame based compression technique, number of steps involved in compressing the video as been reduced by eliminating quantization, zigzag scanning and run length encoding steps. The proposed algorithm generates surveillance grade video quality, which can be implemented with microcontrollers for scaling down the cost of cameras. From the proposed DCT based compression techniques, all videos under the study have same amount of compression ratio for given number of coefficients and PSNR values in order maintain constant transmission bit rate.

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