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Efficiency of 3D-DCT in Improving Video Quality

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Abstract
The paper presents a comparison of adaptive three dimensional discrete cosine transform (3D-DCT) based motion level prediction algorithm which finds the optimal cube for 3D-DCT based compression technique by analyzing the motion content of the video sequence, Normalized Pixel Difference and Variable Temporal length algorithms. Peak Signal to Noise Ratio (PSNR) has been taken as measurement in identifying the quality of video. It is proved Experimentally that instead of motion compensation technique, the 3D-DCT based motion level prediction algorithm gives better performance in terms of reduction in the data rate and improves the encoding process.

Keywords
Video Signal Processing, 3D-Discrete Cosine Transforms, Peak Signal to Noise Ratio, Video Compression

I. Introduction
Many video compression techniques depend on reducing the spatial and temporal redundancy by motion compensation and prediction. These algorithms have complex motion estimation and prediction algorithms and also no symmetry exists between encoding and decoding block. 3D-DCT is an alternate approach for video compression techniques because it possesses the de-correlation and energy compaction property. Concentration of energy in spatial domain can be achieved by applying 2D-DCT. Along the temporal domain, computing one more 1D-DCT will give the similar concentration of energy in the temporal domain which leads to 3D-DCT. Variable temporal length algorithm has been discussed in finding the maximum allowable temporal length but it is required for determining the memory space to store the video frames for processing. Normalized pixel difference (NPD) algorithm was used where cube construction is uneven for a single block.

II. Variable Temporal Length Algorithm
Variable temporal length algorithm was taken into consideration for an adaptive adjustment of the length of the 3-D block in the temporal direction. It relies on the local activity in the image sequence. The temporal length is varied instead of a fixed one. First, the image sequence is divided into a number of time windows, which is a fixed number of image frames of the original image sequence. The quality of the algorithm is increased if a longer time window is used. However, the memory requirement is also increased. Then, each time window is subdivided into a block sequence with a spatial dimension of M 2 N. The pixel intensity in each block sequence can be mathematically represented as I(x; y). To keep each 3-D block having only low motion activity, a scene change detector has to be used to identify the scene change of each block sequence independently, and this has to be done before the interframe transformation.

An adaptive Block Filter (ABF) is developed for the minimization of an error function

$$E(P) = \sum_{j=0}^{P} \sum_{x=0}^{M} \sum_{y=0}^{N} e[Fj(X;Y)]$$

The above equation shows the error function, which relies on the possible optimal locations of the scene change planes, can be efficiently computed with dynamic programming

The required number of scene change planes in each block sequence rely on its motion activity; therefore, it is reasonable to adaptively select the number of scene change planes, P, such that the minimum value of the error function could be less than a predefined threshold. In other words, the value of P in a block sequence increases when it contains many motions. On the other hand, smooth and minor temporal variations of the block sequence give small P this method can achieve the optimal discontinuity planes of each block sequence, but a large demand of computational effort is unavoidable.

III. Normalized Pixel Difference Algorithm
An algorithm (NPD) was suggested with a variable size of the video cube, which is dynamically found based on the level of motion in every cube. Therefore, the motion analyzer is the first block in the encoding algorithm which partitions a video sequence of eight consecutive frames into video cubes. Here, 16× 16× 8 video cubes are used for motion analysis. Then, for every video cube, the motion analyzer determines the Normalized Pixel Difference (NPD) between the first and eighth frame. Depending on the calculated NPD value, the motion in a block is evaluated as:

No motion if $NPD \le t_1$

Low motion if $t_1 \le NPD \le t_2$ High motion if $NPD > t_2$

Number of experiments conducted to determine values for thresholds t_1 and t_2, When the motion analyzer detect "low motion", the technique is applied to entire 16×16×8 cube. However, if a region is known as "high motion" region, the cube is subdivided into 8× 8×8 cubes, In this way, for high motion regions the algorithm will produce better quality, however for low motion and no motion regions high compression ratios will be achieved.

After the pixels are converted into the frequency domain coefficients, the algorithm performs quantization and Huffman encoding. Since, Most of the energy is concentrated in a few low-frequency coefficients, high –frequency coefficients have zero or near- zero values, and need not to be encoded. The quantizer decreases the amplitude of the coefficients that have no contribution to the quality of video, with the purpose of improving the number of zero coefficients. The entropy encoder further compresses the data using a lossless variable length Huffman algorithm.

IV. Motion Level Prediction Algorithm

A new energy based algorithm proposed for determining the motion level of the cube. The cube for which the motion level has to be determined is subjected to 3D-DCT method. DCT is having excellent energy compaction property. Once it is taken along all the 3 dimensions the coefficients are concentrated along the major axis of the cube. Once the cube size is known, then each cube is processed through all the blocks starting from taking 3D- DCT followed by quantization, zigzag scanning and variable length coding to get the compressed video as given in the following figure.

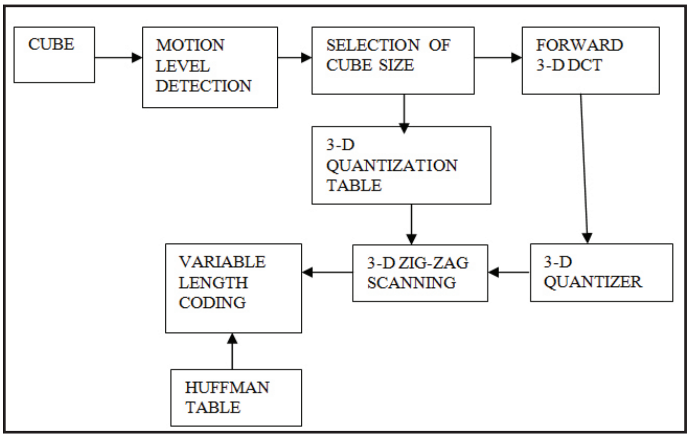


Fig. 1: Block Diagram of Adaptive 3D-DCT Encoder

The same process is reversed to get the original sequence of the video. 3D-DCT can be obtained by taking one dimensional DCT along the three dimensions [Nr × Nc × Nd]. Quantization plays a vital role in the compression technique. In order to transmit the video sequence with reduced distortion and bit rate, proper selection of values for the quantization table is required. Here 2D quantization table cannot be used that is applicable to for standard video compression technique because of 3D-DCT. Hence need for 3D Quantization table. The entries in the table are chosen by analyzing the dynamic range of DC and AC coefficients. These coefficients place a greater role in the quantization.

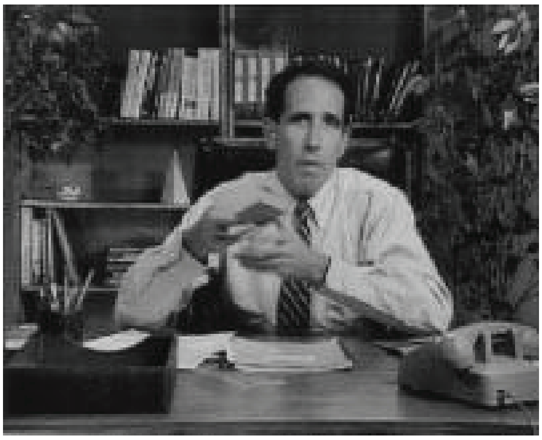
V. Results

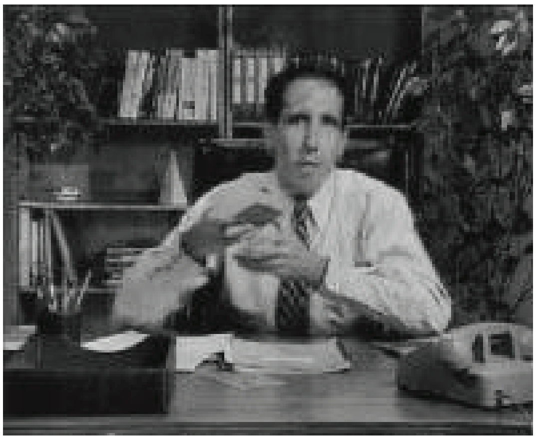
Peak Signal to Noise Ratio (PSNR) is used as a measure to determine the video quality of the compressed video.

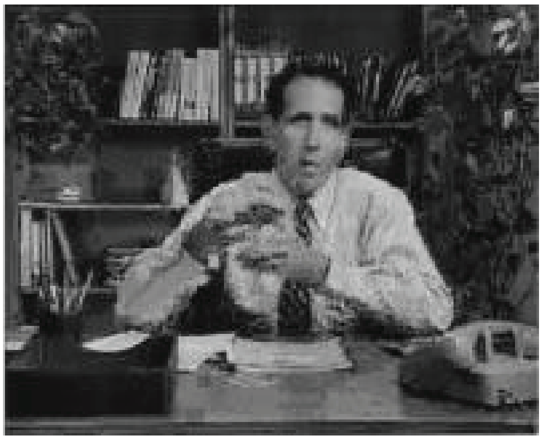
PSNR= 10 $\log_{10}$ (2552/ Mean Square Error) db

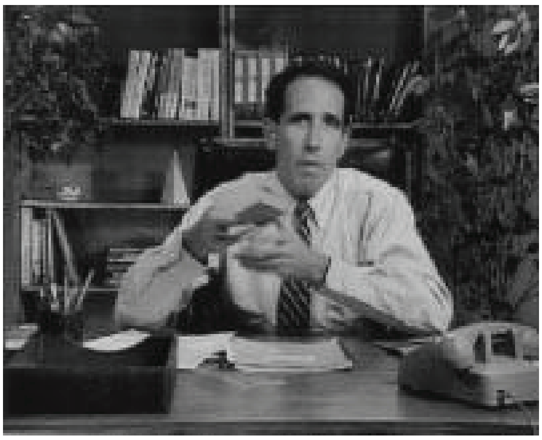
Here the results of above mentioned algorithms, simulated and verified using Mat lab. The data rate and the PSNR parameters are considered for comparison as shown in the following table.

Soccer					
Proposed 3D-DCT based algorithm		NPD algorithm		VTL algorithm	
Data rate Kbps	PSNR (db)	Data rate Kbps	PSNR (db)	Data rate Kbps	PSNR (db)
252.5067	28.3483	402.5818	28.5657	605.9766	29.4104
305.4471	29.3156	435.1937	29.6731	672.6321	30.3155
359.0143	30.5428	453.9456	30.3515	724.5770	31.2551
385.0946	31.2714	474.3280	31.1476	800.4603	32.1289


(a). Original video


(b) Normalized Pixel Difference coding


c) Variable Temporal Length coding


d) Motion Level Prediction 3D-DCT algorithm

VI. Conclusion

An adaptive cube selection algorithm for 3D-DCT based video compression technique will dynamically select the cube size relative to the motion level of video sequence. Motion level is found by energy based adaptive 3D-DCT based method, based on that suitable cube size is chosen. Salesman test sequence is taken for evaluating the proposed algorithm by calculating data rate & PSNR and compared with the existing algorithms. Experimental result reveals that this algorithm outperforms MPEG-2 and other existing 3D-DCT based compression algorithms. Better performance is achieved by adopting variable cube size, which in turn reduces the process complexity of the algorithm and significant rise in the PSNR value. Because of its high compression ratio and reduced process complexity this algorithm is well suited for video surveillance application.

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