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Rate Distortion Optimized Motion Estimation for Video Compression Using Improved Quad Tree Algorithm

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Abstract

In this paper the application of quadtree algorithm in the situation analysis of natural ecology is used to estimate rate distortion optimized motion of video compression. This algorithm is applied in the natural ecology protection system, it can locate the region which pollutes quickly in the map, provides the scientific basis for the government in carrying on the ecological environment and using the resources environment sustainable. State of the art technologies like multiple reference frame (MRF), Variable Size Block Matching (VSBM) and quarter pixel accuracy are used in video coding standards and strive to reduce temporal and spatial redundancies and preserve life forms and natural resources. It is evident from the literature review that around 70 %-90% of total computational power is used in motion estimation. Thus, reduction in redundancy and computational complexity of motion estimation has one of dominating taken research area in the area art and situation analysis of natural ecology. Of the many techniques available to reduce computational complexity along with redundancy in motion estimation on the basis of art principles, quadtree based algorithms for variable size block matching (VSBM) is one of the most sought after which is way to merge environmental studied and art technologies. In this investigation, an effort has been made to apply quadtree algorithm in situation analysis of natural ecology, which is based on edges homogeneity and is in conformity with environmental principles. This algorithm permits adaptive bit allocation between Displaced Frame Difference (DFD) and Motion Vector Field (DVF). The rate distortion optimization (RDO) allows for trade-off between distortion and rate, it is build based upon quadtree with active and inactive region using edges homogeneity present in the frame. Experimental results using ecological factors and improved quadtree algorithm and A* prune algorithm optimization that reveals total bits for different multi constraints shortest path. The improved motion estimation algorithm based on the philosophy of quadtree leads to substantial improvement in the situation analysis of natural environment and is also significantly helpful in applying algorithm technologies to ecosystem and living species.

Keywords: quadtree, ecological equilibrium, situation analysis of natural ecology, motion estimation, A* Prune algorithm, ecosystem

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INTRODUCTION

As a result of the urbanized advancement aggravating, the ecology uses quadtree algorithm to reduce destruction of ecosystem balance which worsens the human survival environment, thus the society and ecology development need to be coordinated. Therefore in our fast developing economic society, the environmental protection and ecology construction ideas should be strengthened. Today the ecology construction unceasingly needs to strengthen the national territory resource management. The ecological environment information has the multi-domains, the multi-professions, the multi-varieties and the complex characteristic. This paper attempts to merge the application of quadtree algorithm in the situation analysis of natural ecology and technology of art.

Technology of Art is a worldwide art movement, the philosophy of which is based on awareness, the harmonic coexistance of human beings and nature. It is a revitalizing movement in terms of materials used in works of art, which are in many cases, recycled and natural at the same time. Most of them emphasize the beauty of nature as a masterpiece, but one which is as fragile and vulnerable as our own life. Environmental art is an art genre and artistic practice that seeks to preserve, remediate and/or vitalize the life forms, natural resources and protect environment, by applying the principles of quadtree algorithm to living species and their habitats throughout the lithosphere, atmosphere, biosphere, and hydrosphere, including wilderness, rural, suburban and urban locations.

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Joint Video Team (JVT) which is formed by combining two premier international standardization organizations, ISO/IEC and ITU-T proposed H.264 AVC and H.265 High Efficiency Video Coding (HEVC), which are the most popular video coding standards (Ahmed et al. 1984, Şengül et al. 2018). Some of main goals of this video codec are to improve compression performance and reduction of bit rate. These goals are achieved at motion estimation part of encoder in video codec with variable block size and multiple reference frame (MRF) by minimizing the numbers of blocks and prediction error using variable block size matching (CCITT Recommendation 1989).Variable ecological art techniques brought a significant change in quality of the video and are therefore found implemented in advance video coding standards like H.264 and H.265 HEVC but is also the most time-consuming component at encoder end. A number of new algorithms have been proposed by researcher for reducing the computation complexity and adaptively selecting the block sizes (Sullivan and Baker 1991).

In VBSM algorithms, complex motion can be described by smaller blocks while stationery content or uniform motion by larger blocks. However, selection of an appropriate block is one of the biggest problems in applying art principles to ecology and this gives rise to an interesting optimization problem without an efficient solution to this problem and is termed as NP hard. This practical problem can be tackled by using ecological factors and quadtree decomposition where each node has four children or none (Shultz and Dunbar 2006, Hortu et al. 2017). At top of quadtree, block size is 16*16 and at bottom of 3rd level it is 4 * 4. The quadtree is pruned in active region and inactive region according to some threshold on edges present in frame to obtain blocks which are of variable sizes.

The rest of paper has been organised in the following order. Discussion on the quadtree technique and the method based on ecological art principles which is used for video compression is presented in section II. Dijkstra's algorithm considering multi constraint shortest path and rate distortion optimization is discussed in section III. The efficiency of the proposed edge-based quadtree algorithm in order to estimate the motion of the video compression without compromising on the big trade and computational complexity is highlighted in Section IV with the help of the experimental results. Section V concludes the findings of the study (Sullivan, Baker 1994).

CONTENT BASED QUADTREE ALGORITHM FOR VIDEO COMPRESSION

In order to find the optimal rate distortion in video compression by considering fixed or Variable Block Sizes (VBS) block matching algorithm has seen a successful implementation. The efficiency of the encoding by using VBS is based on the fact that VBS allows for representation of active regions with the help of more bits, in comparison with the less active ones. Whereas, in fixed block size motion compensated prediction technique, an equal importance is given to all the regions of the picture based on temporal prediction similarity (Sullivan and Wiegand 1998).

Brief Review of Quadtree Decomposition

There are numerous techniques to match variable block size in motion estimation; one of the vital techniques among them is quadtree which finds significant contribution in motion estimation. In this method, each of the frames is first considered and divided into four number of blocks of size 16*16, after that each of the 16*16 blocks is considered and divided into four 8*8 blocks, which in turn is again sub divided into four 4*4 blocks. A decision criterion is applied to see if each variable size block should be encoded as single 16*16 block or further or four independent 4*4 blocks.

Each block is then discrete cosine transform transformed followed by quantization to obtain compressed frame. The powerful technique of quadtree decomposition provides 2-D homogeneous region in the frame either top-down or bottom up quadtree decomposition procedure. A 2N*2N image block is decomposed into an $(N-n_o+1)$ level hierarchy of square blocks with the help QT structure. The blocks produced by this decomposition at level n has a size of 2n*2n, where, $0 \leq n_o \leq N$ as shown in **Fig. 1**.

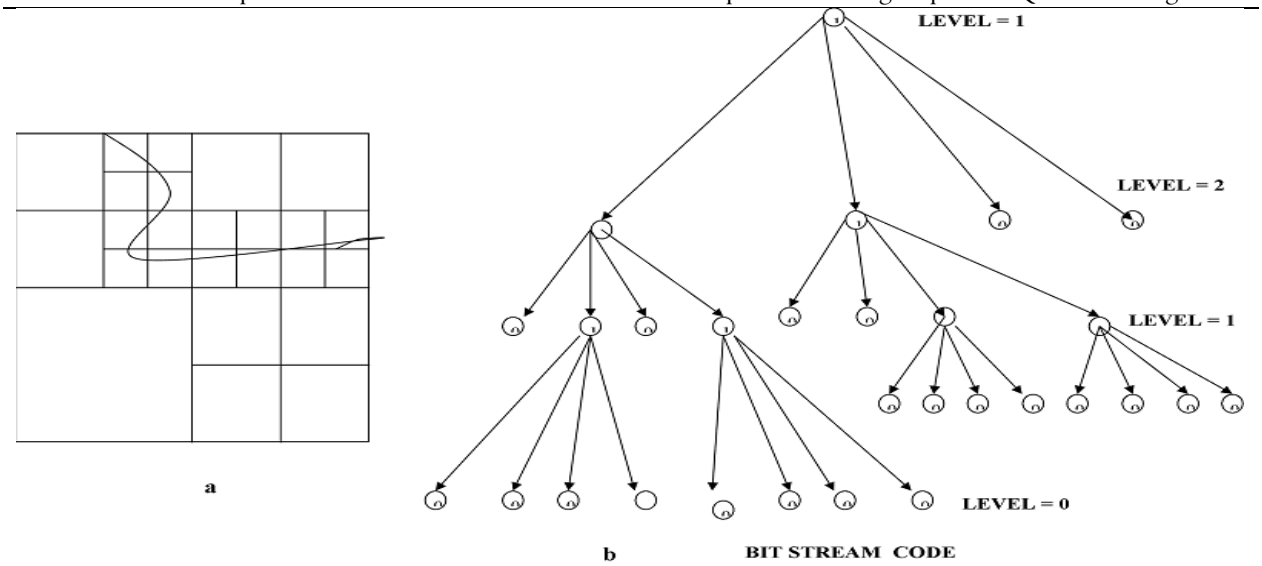

Fig. 1. Frame decomposition Using Quadtree and its presentation

Ecological Factors and Improved Quadtree Decomposition for Video Compression

Block based motion estimation algorithms are extensively used to exploit the temporal redundancies in video coding. But it is very difficult to estimate accurately the blocks located on boundaries of moving objects. As it is well known fact that human eyes are sensitive to edge details, therefore if edge detection techniques are including with motion estimation which improves the quality of the video. Clark (1985) has suggested a fresh technique by incorporating edge matching techniques to perfectly predict the motion of moving objects but at expense of increase in computational complexity. This drawback has made these techniques unavoidable in real time applications. One of the best technique proposed in De Forni and Taubman (2005) based on edge matching criteria, provides good motion estimation and the motion compensated frames comparable with the original frames. This method reduces the computational complexity significantly and provides the results as good as the intensity based full search algorithm (Wiegand et al. 2003).

The standard quadtree decomposition algorithms used in many image compression applications Grosky and Jain (1983) show poor rate distortion performance and creates blocking in the reconstructed image. These problems can be solved by improving rate distortion performance with optimal threshold adjustment on edges present in the active region of frame and assign optimal bits allocation for leaves coding. In this paper, we have presented an ecological factors and improved quadtree algorithm for motion estimation based on one of the important feature, namely an edge intensity present in given frame. Edge detection technique is used to produce an excellent image quality (Ortega and Ramchandran 1998). In this proposed Quadtree decomposition, performance of 3*3 edge detector as used for homogeneity decision is investigated. The new quadtree decomposition algorithm with threshold on edges is as follows:

1. Find number of edges and edge intensity at each level using 3*3 edge detector based on active and inactive regions present in the frame. Enter the threshold value of edges for each block in current frame.
2. If number of edges in active region is greater than threshold value then split the parent node into 4 children nodes.
3. Otherwise don't split region of interest and assign motion vector.
4. Repeat steps 2 & 3 for each 16*16, 8*8 and 4*4 micro-block present in current image.

Now to find optimal solution, coding bits are split into displaced frame difference (DFD) and displaced vector field (DVF) that closely resemble the size of micro-blocks. This problem escorts to rate distortion optimization in video compression. Lagrange multiplier is used to trade off between the bit rate and distortion. Lagrange multiplier optimization is gaining importance because of its effectiveness, conceptual simplicity and evaluate done in an optimized fashion (Shukla et al. 2005). Lagrange multiplier optimization technique is used for calculating optimal K- multiple constraints

shortest paths. In the next section, K- multiple constraints shortest paths are found using A* prune algorithm subject to multiple user defined constraints such as rate and distortion (Wiegand et al. 2003).

PRUNE ALGORITHM FOR K-MULTIPLE CONSTRAINTS SHORTEST PATHS IN VIDEO COMPRESSION

The block matching technique is the most popular tool in motion estimation and compensation, used for video compression techniques and Rate Distortion Optimization (RDO) problem is related to it. RDO problem is related to the family of NP hard problem which uses Lagrange's parameter to solve and find constrained path with some constraints which is to be achieved. As bandwidth available for transmission is a dynamic parameter, whenever requirement changes, it MCSP (Multiple Constraints Shortest Path) procedure can be used effectively each time to find the best possible optimal solution with acceptable bit rate with reasonable loss in image quality. It is always time consuming to use all MCSP each time for finding best feasible solution. In order to find the best feasible solution in least possible time according to variation in dynamic parameters, K-MCSP (K-multiple constraints shortest path) method can be considered. Considerable reduction in time can be achieved as the selection of the best feasible path is done from multiple pre computed paths. A* prune algorithms is used for MCSP which allows for controlling the contribution of different constraints simultaneously and also allows to choose from K paths which are produced due to variation in the dynamic parameters. In this work, A* prune algorithm is used to solve RDO problem. Lagrangian bit allocation techniques is used for an efficient bit allocation between DFD (D) and DVF(R) given by

$$J = D + \lambda * R \tag{1}$$

where λ is Lagrange Parameter. Since dynamically changing constraints like bandwidth or quality of services, we proposed to use K-MCSP algorithm for finding one or multiple feasible paths subject to multiple constraints.

Problem Definition for K-MCSP Algorithm

Considering a network with graph G= (V, E), where V= set of nodes formed by quadtree and E= set of links in quadtree. Each link (i, j) ϵ E is associated with R non negative and additive QoS: $w_r(i, j)$, r= 1, 2,-,-, R. The cost function W_o defined as:

$$W_o(i,j) = \sum_{r=1}^{R} a_r * w_r(i,j) \tag{2}$$

Now to find the first K-MCSP from source (s) to destination (t) node with constraints on rate and distortion is

$$w_r(p(s,t) \stackrel{\text{def}}{=} \sum_{\substack{(i,j)\epsilon p(s,t) \\ \forall(1,\ldots\ldots,R)}} w_r(i,j) \leq c_r(s,t) \tag{3}$$

A* search algorithm Sullivan, Wiegand (1998) with proper pruning technique is used to solve K-MCSP problem defined in eq. 3. In this paper, five best feasible multiple constraints shortest paths are found with two constraints i.e DVF and DFD. The complete flowchart for finding the best feasible K-MCSP paths using improved ecological factors and quadtree algorithms with A*prune algorithm is shown in **Fig. 2**.

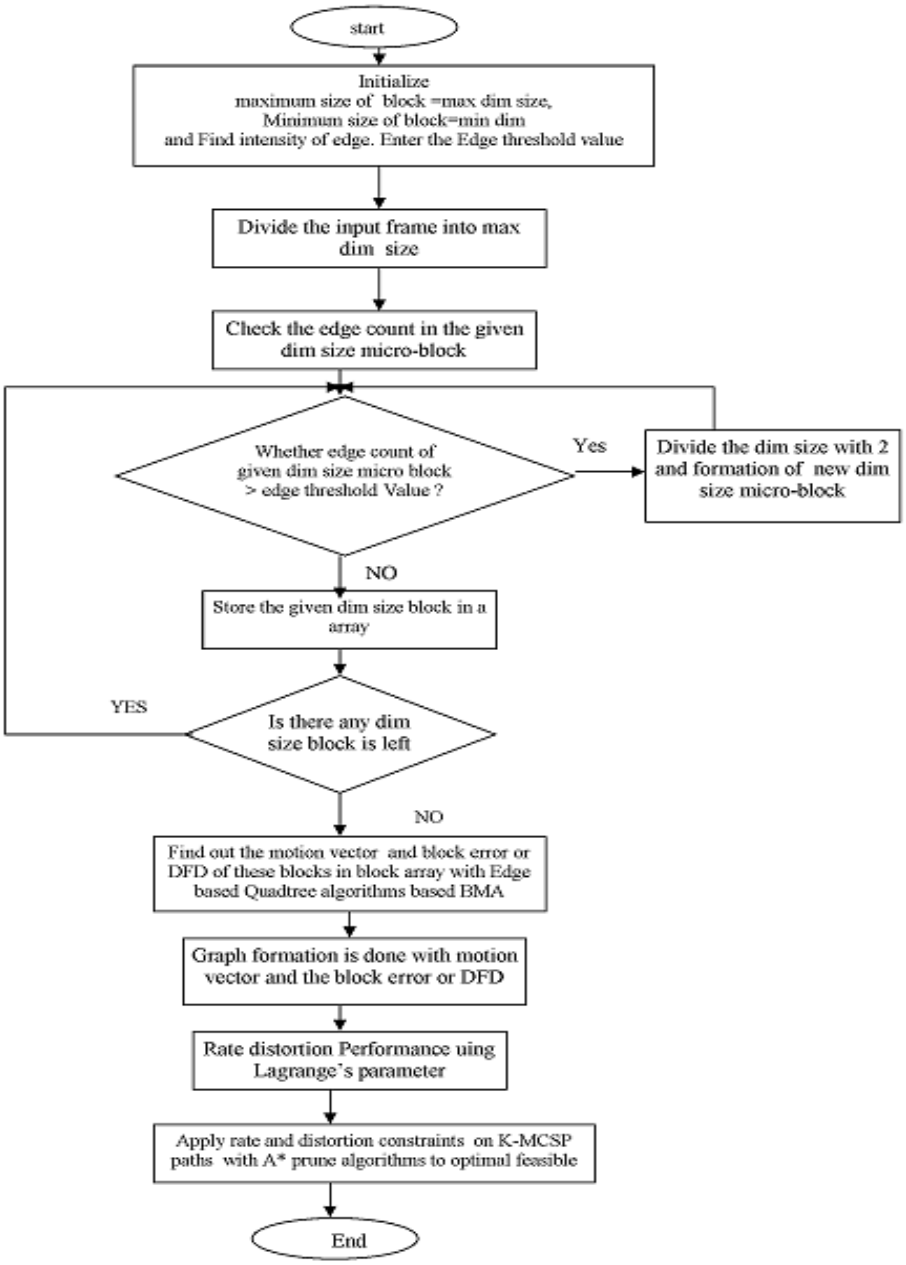

Fig. 2. Flowchart of the proposed algorithm

EXPERIMENTAL ANALYSIS OF K-MCSP USING ECOLOGICAL FACTORS AND IMPROVED QUADTREE WITH A* PRUNE ALGORITHMS

Extensive experimental results have been carried out on several test sequences such as Mother Daughter and Foreman for ecological factors and improved quadtree algorithm with variable threshold on edges. Displacement field difference (DFD) i.e. distortion and displaced vector field (DVF) i.e. rate are calculated for each block size 16*16, 8*8 and 4*4 respectively. The DVF are calculated using exhaustive/ full search for motion estimation and motion vectors are coded with DPCM technique. Displacement field difference (DFD) is coded with Huffman entropy coding. The performance of proposed approach is evaluated using extensive experimental simulation conducted on a 2.0 GHZ PC with 2 GB main memory with MATLAB version 12.0. It is shown from the experimental simulation that the performance can be dramatically improved by reducing the bits requirement for encoding the motion vectors and allocating the data bits to the residual encoding, which eventually improves the quality of the picture. With very low bit rate applications

Table 1. Rate Distortion Performance with improved and traditional quadtree algorithms for Foreman. Video sequence

Path → / Measuring Parameters ↓	Video Frame: Foreman Frame 2 & 5 Rate constraint=2000 Distortion constraint=10000				
	1	2	3	4	5
Rate	1652	1766	1802	---	---
Distortion	8604	8489	8459	---	---
Total bits	10256	10255	10261	---	---
PSNR	30.3298	30.3298	30.3298	---	---
Time complexity for each path	77.3492	79.2454	81.0518	---	---
Traditional Quadtree algorithms	Video Frame: Foreman Frame 2 & 5 Rate constraint=2000 Distortion constraint=10000				
Rate	1610	1694	1784	1814	1862
Distortion	9841	9743	9653	9625	9585
Total bits	11451	11437	11437	11439	11447
PSNR	31.3829	31.3829	31.3829	31.3829	31.3829
Time complexity for each path	89.5065	90.9425	92.6978	94.4774	96.4104

Table 2. Rate Distortion Performance with improved and traditional quadtree algorithms

Path → / Measuring Parameters ↓	Video Frame: Mother Daughter 2 & 5 Rate constraint=2000 Distortion constraint=10000				
	1	2	3	4	5
ecological factors and Improved Quadtree Algorithms					
Rate	644	668	722	776	848
Distortion	1886	1858	1804	1759	1711
Total bits	2530	2526	2526	2535	2559
PSNR	33.8893	33.8893	33.8893	33.8893	33.8893
Time complexity for each path	86.9141	88.2778	89.578	90.8217	92.4385
Traditional Quadtree algorithms	Video Frame Mother Daughter 2 & 5 Rate constraint=2000 Distortion constraint=10000				
Rate	740	812	890	---	---
Distortion	2739	2667	2602	---	---
Total bits	3479	3479	3492	---	---
PSNR	34.453	34.453	34.453	---	---
Time complexity for each path				---	---

Table 3. Rate Distortion Performance with improved and traditional quadtree algorithms for H.265 HEVC

Path → / Measuring Parameters ↓	Video Frame: Mother Daughter 2 & 5 Rate constraint=2000 Distortion constraint=10000				
	1	2	3	4	5
Rate	260	338	356	404	
Distortion	2058	1968	1948	1900	---
Total bits	2318	2306	2304	2304	
PSNR	33.8893	33.8893	33.8893	33.8893	
Time complexity for each path	113.8869	115.4906	117.2336	119.1637	
Traditional Quadtree algorithms	Video Frame Mother Daughter 2 & 5 Rate constraint=2000 Distortion constraint=10000				
Rate	416	428	470	536	554
Distortion	2872	2859	2814	2848	2731
Total bits	3288	3287	3484	3284	3285
PSNR	34.453	34.453	34.453	34.453	34.453
Time complexity for each path	95.9315	97.0334	98.1489	99.3277	100.5484

this coding strategy proves to be very advantageous. The number of bits required for DFD and DVF for each of the K shortest paths is computed along with the corresponding PSNR values. The best of the shortest path is selected for reconstruction of the frame in our study. **Tables 1-3** show multiple constraint shortest paths for different test sequence with their rate (DVF), distortion (DFD), PSNR and computational complexity with and without ecological factors and improved quadtree algorithms for motion estimation respectively. The constraints for both Rate and distortion as per our A⋆ prune algorithm to given values below:

K: 5 DVF constraints: 3000 DFD constraints: 12000 Count: 24334 List Size: 10

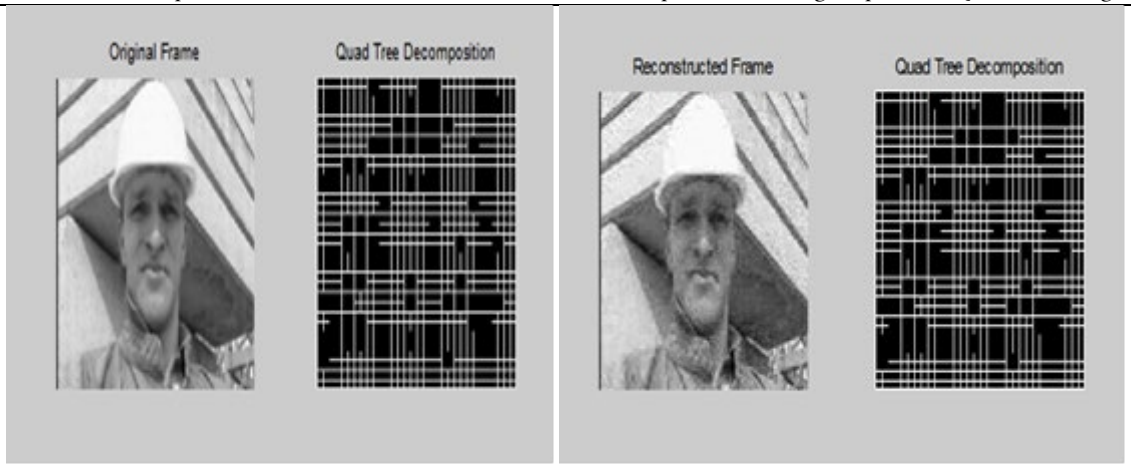

Fig. 3. Original and Reconstructed Frame 5 of Foreman Video Sequence for path 3 for ecological factors and improved quadtree algorithms

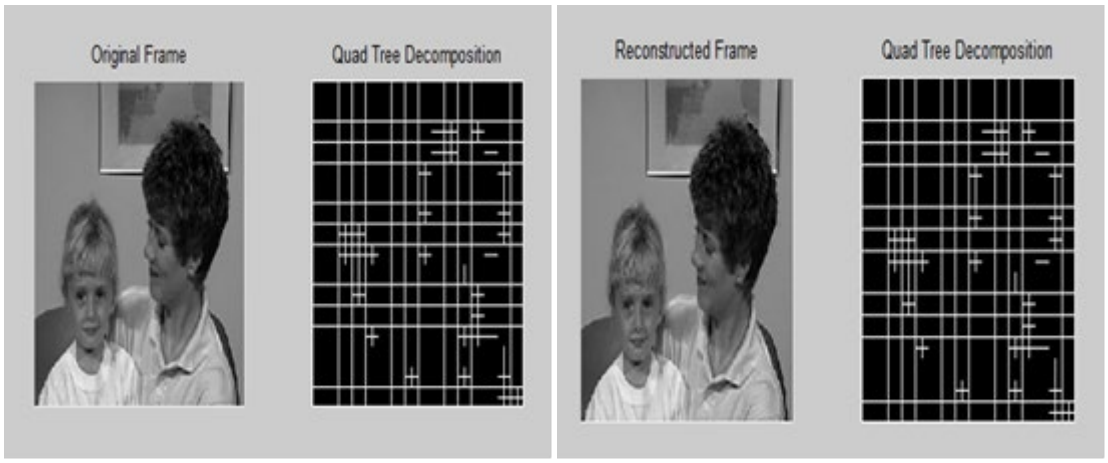

Fig. 4. Original and Reconstructed Frame 5 of Mother Daughter Video Sequence for path 3 using ecological factors and improved quadtree algorithm

Table 1 shows that both DVF and DFD satisfy required the constraints set for rate and distortion respectively. Only three feasible paths are obtained for the given constraints. The total bits and PSNR are shown for each path. It is concluded from **Table 1** that all the paths provided by improved algorithm are feasible solutions, and do not violated the limitation imposed on the constrained. **Fig. 3** shows the original and reconstructed frame along with quadtree structure of foreman video sequence constructed by ecological factors and improved quadtree algorithm. Similarly **Table 2** shows that both DVF and DFD satisfy required the constraints set for rate and distortion respectively for mother daughter frame. It is clearly shown from **Table 2** that five feasible paths are obtained for the given constraints using our ecological factors and improved quadtree compared to only three paths in traditional quadtree algorithm. **Table 3** shows the results obtained for H.265 HEVC for improved quadtree algorithm. It is concluded from **Table 3** that all the paths provided by improved algorithm are feasible solutions, and do not violated the limitation imposed on the constrained. **Fig. 4** shows the reconstructed frame of mother daughter for path 3 for H.264 and H.265 HEVC respectively. All the above tables shows that total bits are decreases up to 10-20% but in H.265 HEVC it decreased by 30-35%. The DVF in H.265 HEVC approximately declined by 40-50% which satisfies the criteria mentioned in literature of H.265 (Vaisey and Gersho 1987).

CONCLUSION

In order to reduce the computational requirement of the encoder, many researchers active in the interdisciplinary field of art and natural environment have focused in the area typically acknowledging the fact motion estimation typically represents around 70 to 90% of an entire encoder computational requirement. In this paper, an attempt has been made to introduce a computationally efficient and improved quadtree algorithm for situation analysis of natural ecology. This

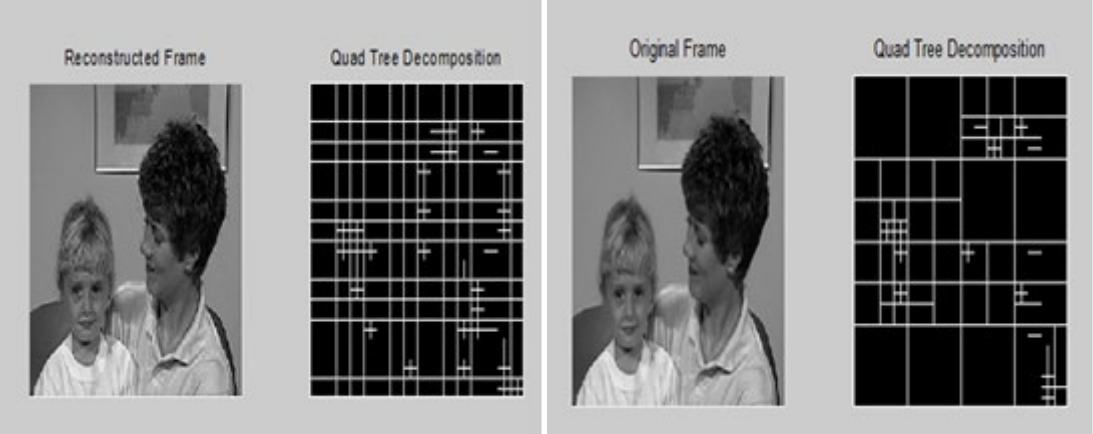

Fig. 5. Original and Reconstructed Frame 5 of Mother Daughter Video Sequence for path 3 for H.264 and H.265 HEVC

algorithm is applied in the natural ecology protection system, it can locate the region which pollutes quickly in the map, provides the scientific basis for the government in carrying on the ecological environment and using the resources environment sustainable.

Lagrange multiplier optimization technique is used for minimizing the sum of distortion of block and 'λ' times bits needed to code it, where 'λ' is the Lagrangian parameter. The pruning /merging motion estimation algorithm which is based on the philosophy of quadtree structure leads to substantial improvement in the quality of the reconstructed picture without much distortion and is also significantly helpful in reducing the computational requirements as shown in **Fig. 3**, **Fig. 4** and **Fig. 5** respectively. A* prune algorithm for multiple constrained shortest path is used for variable size block matching technique which generates lower overall bit rates without compromising both DVF and DFD constraints simultaneously and satisfying both as well.

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