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An Adaptive Video Compression Technique for Resource Constraint Systems

Shreelekshmi R, Sruthi S

***Abstract*—As display devices become more and more vivid, and people demand more perfection in video quality, it is necessary to maintain the natural colors, which is in RGB domain. Because of its huge size, managing videos in RGB color space is not practical. Recent years witnessed a rapid evolution in the area of Video Compression Technology. Most of them use complex algorithms to handle Temporal Redundancy and as a result they are very time consuming. Accordingly, there is a high demand for less complex video compression techniques for handling RGB videos. This paper presents a new RGB video compression technique developed with less time complexity while ensuring an acceptable level of perceptual quality and bandwidth requirements. The proposed system performs Intra-Frame compression for removing Spatial Redundancy followed by Run-Length Encoding and an additional level of bit reduction on the resultant data. This system needs very less processing time, due to the simplicity of techniques used. As compared to the latest and most efficient compression standard HEVC, the proposed system takes much less time for its execution.**

***Index Terms*—Bit-Plane Slicing, Bit-Plane Reduction, Run-Length Encoding**

I. INTRODUCTION

A video is a sequence of still images that are captured at regular time intervals. A video in its uncompressed form may consume a huge amount of storage space and bandwidth for transmission. For example, a 10 seconds RGB 8:8:8 video with resolution 1920x1080 and having a total of 240 frames requires 1920x1080x240 pixels to represent it. Since each of the R, G and B color values in a video is represented using 8 bits, 24 bits is needed to represent a single pixel and a total of 1920x1080x24x240 bits which is equal to 11,94,39,36,000 bits is needed to represent the whole video. Since the duration of the video is 10 seconds, it has a bit rate of 1, 16, 64,000 Kilobits/second which is not practical when the bandwidth is limited. So in order to reduce resource utilization, it is better to compress the massive amount of data involved in a video before storing or transmitting it. Such situations demand *Video Compression*, a type of data compression that is used to remove redundant information from a video and to discard parts of the video that will not be recognized by Human Visual System (HVS). The process of reconstructing the original video from a compressed video is known as *Decompression* [1] [2].

Motion JPEG (1990), H261 (1990), MPEG-1 (1992), H.262/MPEG-2 (1994), H.263 (1995) [4], H.264/MPEG-4 AVC (2003) and H.265/HEVC (2013) are widely used compression standards defined by ISO and/or ITU. H.264/MPEG-4 AVC [5]-[7] is a project jointly done by ITU and ISO. HEVC (High Efficiency Video Coding) [8], [9], the standard defined by ITU and ISO is the most efficient video compression standard available today. But these standards use complex and time consuming algorithm to perform temporal redundancy removal.

Recently, an algorithm which can compress RGB images in linear time complexity has been introduced [11]. This algorithm uses a very simple technique called Bit-Plane Reduction in which visually insignificant data can be removed to compress an image. Next level compression is done using Run-Length Encoding.

(a) (b)

Fig.1: (a) Original Lena.bmp (b) Lena.bmp after retaining only the most significant bit-plane [11].

Through this research they have proved that the perceptual quality of an image can be maintained even after the removal of 4 lower order bit-planes and the image can be recognized by retaining only the MSB plane. The result after the removal of all the seven lower order bit-planes (retaining only the MSB bit plane) is as shown in Fig.1 (b). In comparison with TIFF, for the same computational complexity, this algorithm gives better compression ratio. It can attain better compression ratio with much less time complexity as compared to JPEG. This research work [11] [12] contributes the idea of implementing Bit-plane Reduction technique for video compression.

II. PROPOSED SYSTEM

This section gives an overview about a new less time complex video compression technique for RGB videos. The objective of this work is to develop an RGB video compression technique with less time complexity, while ensuring an acceptable level of quality, storage requirements and transmission requirements based on the application.

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***** Correspondence Author (s)
Dr. Shreelekshmi R*, Department of Computer Science, LBS Institute of Technology for Women, Poojappura, Kerala, India
Sruthi S, Department of Computer Science, LBS Institute of Technology for Women, Poojappura, Kerala, India.

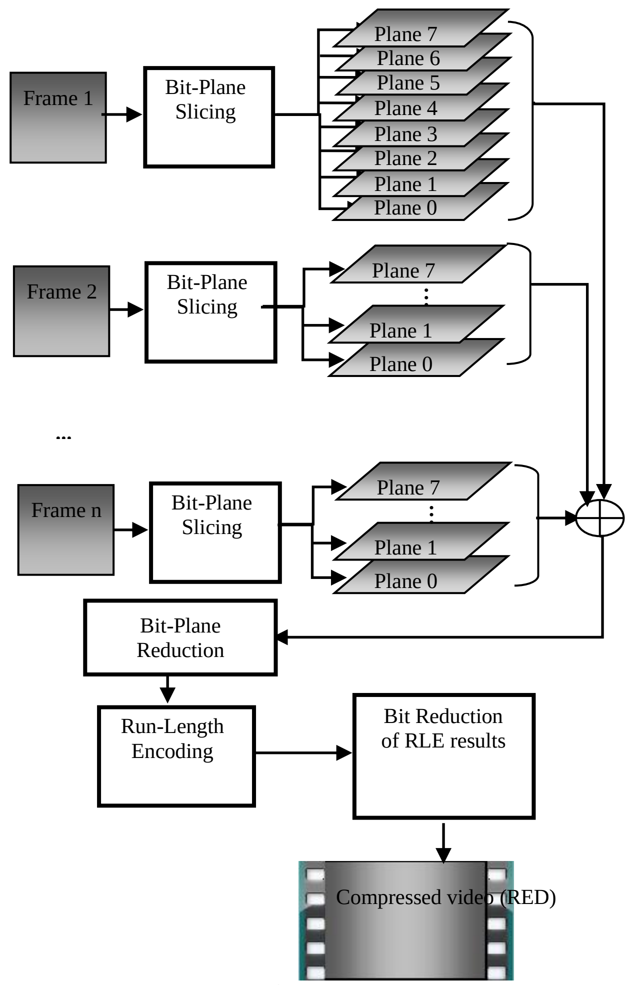


Fig.2: Design of

The proposed system uses four simple techniques for compressing a video. They are:

1. Bit-Plane Slicing
2. Bit-Plane Reduction
3. Run-Length Encoding
4. Bit-Reduction

It implements Bit-Plane Slicing and Bit-Plane Reduction methods for removing Intra-Frame redundancy. The output of Bit-Plane Reduction is encoded using Run length encoding. A further level of compression is achieved by performing Bit Reduction on the resultant data. All of these techniques are less complex and easy to implement. Fig.2 depicts the design of the proposed system.

A. Bit-Plane Slicing

Bit-Plane Slicing [11]-[13] is the process of splitting an image into different intensity levels. Assuming that each of the RGB color components of a pixel is represented using 8 bits where each color plane can be split into 8 bit-planes that are Bit-Plane 0 (LSB) to Bit-Plane 7 (MSB) as shown in Fig.2.

B. Bit-Plane Reduction

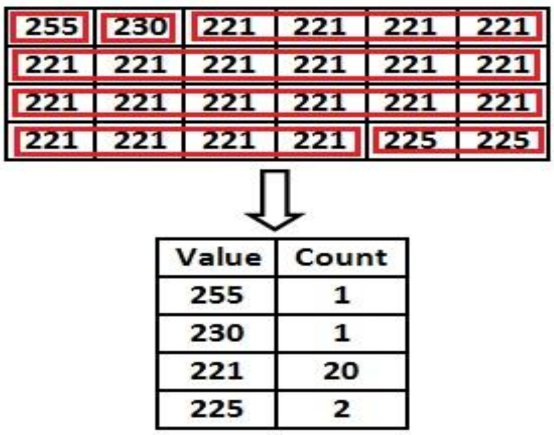
An image (frame) consists of both high frequency and low frequency components. Bit-Plane Reduction [11], [12] is based on the fact that Human Visual System is more sensitive to the high frequency components and so the removal of lower order bit-planes will not cause much degradation in image quality. So the bit-panes which contain low frequency information can be discarded for reducing the size of a video file. If we retain only one most significant bit-plane, we can attain a compression ratio of 1/8 and if we retain seven most significant bit-planes, the compression ratio will be 7/8. The relationship between the number of LSB planes that are discarded and the Compression Ratio is as shown in table 1.

Table1: Relationship between the number of LSB planes discarded and the Compression Ratio

No. of discarded LSB-Planes	Compression Ratio
1	7/8
2	¾
3	5/8
4	½
5	3/8
6	¼
7	1/8

C. Run-Length Encoding (RLE)

Run Length Encoding [1] [2] is the simplest and widely used encoding technique. The basic principle behind Run-Length encoding is to detect sequence of repeated values in an image and replace these sequences with a *(value, count)* pair where the value represents the repeated color value and the count represents the number of repetitions. The sequence of repeated values is also called *runs*.



255	230	221	221	221	221
221	221	221	221	221	221
221	221	221	221	221	221
221	221	221	221	225	225

Value	Count
255	1
230	1
221	20
225	2

Fig.3: Original Representation and Representation after Run-Length Encoding

For example, let the first table in Fig.3 be the actual representation of red plane of a frame. If we are using 8-bit representation for both the *Value* and *Count* Field, the actual representation needs 24x8=192 bits to represent the red plane. The second table in Fig shows the result after performing Run-Length encoding, where a total of (4x8) + (4x8) = 64 bits is needed to represent the same red plane. Run-Length encoding technique is more efficient for videos that contain so many long runs of color values.

D. Bit Reduction

If the size for *Count* field is selected as the size of the largest possible count, then it may end up with a high bit requirement. So, optimum number of bits should be chosen as the size of *Count* field in order to accomplish minimum bit requirement.

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Table 2: Total bit requirement when choosing different size for count field (for the example in Fig.3).

Count	No. of bits to Represent Count Value				
	5	4	3	2	1
1	5	4	3	2	1
1	5	4	3	2	1
20	5	8	9	14	20
2	5	4	3	2	2
Total bits	**20**	**20**	**18**	**20**	**24**

Table 2 shows the total bit requirement when choosing different size for count field. In this example, the 3-bit representation requires only 18 bits to represent the entire *Count* values. So the *Bit Reduction Technique* selects 3-bit representation for *Count* field, in order to obtain minimum bit requirement and thereby reducing the total size. If 3-bit representation is selected for the *Count* field, the actual bit-requirement of 192 bits in the above example will be reduced to (32 + 18) = 50 bits.

III. Compression Algorithm

The algorithm takes the input as a 24 bpp RGB uncompressed video. Since the input is a color video that consists of RGB color frames, each frame is initially divided into R, G and B *Color Planes* and then performs Bit Slicing technique on each of these Color Planes. Based on the application, Least Significant *Bit-Planes* are discarded as per the requirement and then Run-Length encoding is performed to encode remaining bit-planes. Depending upon the nature of the input video, this algorithm calculates optimum bit requirements for its representation.

Step 1: Load the 8:8:8 RGB uncompressed video.
Step 2: For each frame
For each R, G and B planes
Step 3: Perform Bit-Slicing.
Step 4: Based on the application, discard the required number of Least Significant bit-planes.
[End For]
[End For]
Step 5: Perform Run-Length Encoding to encode all the remaining bit planes of each R, G and B planes.
Step 6: Perform Bit Reduction by selecting the perfect Size for RLE Count field.
Step 7: Stop

Since the Bit-Plane Reduction method is used for compression, this algorithm is a lossy one. Using this algorithm, we can compress a video with linear time complexity.

IV. RESULTS AND DISCUSSION

Three 24 bpp RGB uncompressed test videos are used for the performance evaluation. *Kimono1* and *ParkScene* are two Standard Definition (SD) videos with resolution 1920x1080. Both of them have 240 frames with duration of 10 seconds. The third one is *Traffic*, which is a High Definition (HD) video with resolution 2560x1600 and has 150 frames with duration of 5 seconds. The test setup includes i3 processor, 2GB RAM and Ubuntu 14.04 LTS Operating System. The results of these experiments are as shown in Table 3-5. Fig.4-6 shows the outputs of videos Kimono1, ParkScene and Traffic respectively after Bit-Plane removal at different levels.

Table 3: Kimono1, 1920x1080, 240 frames, 10 seconds

No. of MSB planes retained	Time to Encode (seconds)	Perfect no. of bits to represent RLE Count	Bit Rate (Kbits /sec)	PSNR (dB)	Bit Savings (%)
1	124	10	10,131	12.73	99.13
2	128	6	47,926	17.47	95.89
3	141	4	1,14,139	23.31	90.21
4	204	1	2,03,333	29.40	82.57
5	246	1	3,76,030	35.72	67.76
6	273	1	6,37,151	42.70	45.38
7	303	1	9,12,665	51.15	21.75

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Table 4: Park Scene, 1920x1080, 240 frames, 10 seconds

No. of MSB planes retained	Time to Encode (seconds)	Perfect no. of bits to represent RLE Count	Bit Rate (Kbits /sec)	PSNR (dB)	Bit Savings (%)
1	122	7	28,155	12.89	97.586
2	129	5	89,696	17.32	92.310
3	138	1	1,51,063	23.12	87.488
4	191	1	2,64,373	29.37	77.334
5	255	1	4,57,470	35.73	60.779
6	330	1	7,11,269	42.69	39.02
7	375	1	9,67,312	51.14	17.069

Table 5: Traffic, 2560x1600, 150 frames, 5 seconds

No. of MSB planes retained	Time to Encode (seconds)	Perfect no. of bits to represent RLE Count	Bit Rate (Kbits /sec)	PSNR (dB)	Bit Savings (%)
1	147	6	22,751	12.18	96.337
2	180	5	109,583	17.57	92.39
3	192	1	3,52,992	23.36	87.343
4	209	1	5,70,011	29.41	80.208
5	270	1	9,49,908	35.76	67.017
6	369	1	14,91,413	42.69	48.215
7	429	1	21,38,923	51.12	25.732

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Original *Kimono1* Video (SD)

After discarding 7 LSB Planes

After discarding 6 LSB Planes

After discarding 5 LSB Planes

After discarding 4 LSB Planes

After discarding 3 LSB Planes

After discarding 2 LSB Planes

After discarding 1 LSB Plane

Fig.4: Kimono1(1920x1080, 240 frames) after Bit-Plane removal at different levels

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Fig.5: ParkScene (1920x1080, 240 frames) after Bit-Plane removal at different levels

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Fig.6: Traffic (2560x1600, 150 frames) after Bit-Plane removal at different levels

The performance evaluation is done based on Encoding Time, PSNR, Bit Savings and Bit Rate. First we have tested the proposed system using SD videos, *Kimono1* and *ParkScene*. By retaining only one MSB plane, *Kimono1* can be compressed with 99.13% bit-savings and 12.73 PSNR. In the same situation, *ParkScene* attains 97.586% bit-savings with 12.89 PSNR. By increasing the number of retained MSB planes, the quality of videos can be improved. For both *Kimono1* and *ParkScene*, an acceptable perceptual quality has been maintained even after the removal of 5 least significant bit-planes.

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By retaining only one MSB plane, the HD video *Traffic* has got bit-savings of 96.337% with 12.18 PSNR. The algorithm can maintain an acceptable perceptual quality of *Traffic*, by retaining only 2 MSB planes.

From these experiments it can be concluded that, for SD videos, the proposed system can achieve perceptually lossless compression by retaining four or more MSB planes. The perceptually lossless compression on HD videos can be accomplished by retaining three or more MSB planes.

V. CHALLENGES AND FUTURE WORKS

Even though the system is very simple and has linear time complexity, there exist certain challenges in it. The first challenge is that the proposed system works only for RGB 24bpp videos. It is possible to enhance the system by applying the same techniques for compressing videos in other color spaces such as YUV. The second challenge is that the system is designed only for the removal of spatial redundancy. If the temporal redundancy is also taken into consideration, compression ratio can be improved.

VI. CONCLUSION

The interesting factor of the proposed system is that it takes only linear time for its execution. While the latest compression standard HEVC takes hours for execution, the proposed system takes only minutes in order to maintain an acceptable perceptual quality. This system is more suitable for the applications which demand RGB video compression technique that can produce video with acceptable perceptual quality in minimum time.

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Dr. Shreelekshmi R, is Professor and Head of the Department, Computer Science, LBS Institute of Technology for Women, Trivandrum, India. She received her B Tech degree in Computer Science and Engineering from TKM College of Engineering, Kollam, India, ME degree in Computer Science & Engineering from Indian Institute of Science, Bangalore, India and Ph.D. from Kerala University, India. She has won Computer Science of India – the Best PhD Thesis Award for the year 2013. Her research interests include pattern recognition, steganography, steganalysis and image/video compression.

Sruthi S, is currently pursuing her M.Tech degree in Computer Science and Engineering at LBS Institute of Technology for Women, Trivandrum, India. She received her B.Tech degree in Computer Science & Engineering from Kerala University, India.

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