CHAPTER 4

A NOVEL GRAPH-BASED VIDEO COMPRESSION FRAMEWORK COMPATIBLE WITH HEVC

This chapter is the continuation of our preliminary work which precisely talked about a framework namely FVCP for video compression in peak traffic condition for low bandwidth mobile networks. However, the prime focus of this chapter lies in designing an HEVC based video coding framework for the purpose of offering better compression ratio while maintaining the perceptual quality of decoded video content. The proposed model thereby adopts the concept of Graph Theory as an integral part of HEVC compression which also enables applying Lagrangian Theorem to achieve best solutions for the compression.

4.1 INTRODUCTION

With the enormous increase of real-time high-definition video contents, there arises a need of performing adequate compression without affecting the visual contents of a video over low bandwidth networks. Due to the heavier nature of video contents, performing high-end compression significantly affects the perceptual quality of a video. Therefore, the high demand of watching streaming videos online open up the scope of video coding; thereby it has become a promising area of research. The conventional H.264/AVC is a joint effort of ITU-T and MPEG groups preceded by H.263 video coding standard in the year of 2003. Later on, H.264/AVC gained the attention to become adaptive in the industry standard. The extensive design analysis proves that H.264 is highly functional on achieving 50% compression efficiency as compared to its legacy versions. It is also claimed to provide significant support to the high-quality video extensions in low bit rate channels of different portable devices. Although the current scenario in the field of video compression has witnessed a wide range of potential applications which implements H.264/AVC video coding protocol. Despite having all these significances the variation in embedded design of certain mobile devices poses challenges in processing H.264/AVC efficiently. It further leads to very high cost of computation. The dynamic behaviour of mobile networks also causes overhead in power-constraint mobile devices while processing H.264. Hence, there exist a major trade-off between high-end compression and power consumption, also design complexities associated with hand-held devices. Keeping all these facts into the mind our proposed study
aimed to enhance the performance of conventional HEVC by integrating it with a Graph based method for efficient video compression. The further segments of the study are organized by highlighting Problem Formulation, Objective, and Proposed Solution, followed by Conceptual Model and Comparative analysis.

4.2 PROBLEM FORMULATION

Due to the diversity in design methodologies of hand-held devices and various futuristic video compression applications, a major trade-off exists between the cost of computation and efficient high-end compression. However, the complex implementation processes involved in different multimedia processing units of mobile devices compatible with H.264/AVC poses very high cost of computation though it achieves high-performance compression. Therefore it subsequently initiates a major research problem of conceptualizing a less complex design enabled H.264/AVC to achieve high-performance video compression while making least computational overhead.

Compare to previous protocols, the H.264/AVC encoding process involves least complex implementation while considering removal of spatial, temporal and statistical redundancies from a signal to make it more compact and efficient. It performs quantization on macro blocks of 16x16 with respect to special frequency components/coefficients from spatial domain analysis aspects and further performs a considerable amount of compression with effective numerical stability. Still the encoding pipelined process is claimed to generate computation overhead on smart phones. The next segment will formulate the objective of the proposed study which helps conceptualizing the novel concept of video compression.

4.3 OBJECTIVE

The objective of the proposed study in this context concern about designing a novel video compression scheme based on Graph Theory. The objective of the Phase-2 is clearly depicted below.

-To adopt graph theory for to perform video compression compatible for HEVC standards to compress HD videos.

The next section discusses the proposed solution given in the context of supporting the above-stated objective.
4.4 PROPOSED SOLUTION

This chapter introduces a novel concept of video compression using conventional HEVC where a graph-based technique along with Lagrangian theorem plays a crucial role in performing high-end compression with least computational overhead.

- The study aims to validate the performance of the proposed technique by choosing Effective Performance parameters.
- To compare the outcomes of the proposed graph based model with its legacy versions to ensure its effectiveness.
- The schema of the proposed graph based video coding is anticipated to be modelled considering elastic frame-profiling technique which enhance the compression efficiency on a video object with very less processing time.
- It also aims to ensure zero loss of data along with high quality decoded video object.

4.5 CONCEPTUAL MODEL

The conceptual modelling of the proposed system is considered for the purpose of performing high-end compression on multimedia files while retaining the utmost visual quality of the decoded object sequence at the receiver end. The conceptualization of the proposed system is subjected to perform high-end compression on HD videos with the aim of retaining highest visual perception at the receiver end. It also involves a technique called elastic frame profiling method which is derived on the basis of objectifying the numerical coefficients underlying functionalities from the first frame (reference) till the end of test frame using Graph Theory approach. The following Figure 4.1 exhibits the proposed schema of graph based compression integrated with the functionalities of HEVC, Motion Compensation and Lagrangian coefficients measurements. The study extensively performed the HEVC encoding on the top of the encoding process where few of the operational specifications from H.264/AVC are considered in this context.
A deep insight into the video compression model introduced by the study of Sullivan et al. \[56\] reveals the fact that it uses 16 x 16 block orientations to perform H.264 video coding on heavier multimedia files. On the other hand, the study of Kordasiewicz et al. \[57\] enhanced the performance efficiency of conventional uniform block size technique and extended its scope of applicability by considering variable block size method. The proposed study explicitly adopted these two concepts involved into the prior studies and thereby extended the optimality of RD-theoretical trade-off in terms of block size and conventional 16 x 16 orientation integrated with HEVC.

These blocks are often termed as macro blocks and these are also further divided into sub-blocks for the ease of computation and encoding. Segmentation of a macro block initiates encoding over homogeneous regions with low frame rates. It also performs coding on few sets of blocks to reduce the computation overhead and complexities. The proposed study incorporates inter-frame prediction coding for each pixel blocks present in each frame and reference frames. The investigational analysis generates useful information about the effective prediction, thereby the extracted information is sent to the HEVC decoder for the retention of high quality video frames at the receiver end. The concept also applied the principle of Lagrangian coefficient measurement which is formulated as follows:

\[ \alpha = \beta + \gamma \cdot \theta \] (4.1)

In the above stated eq. (4.1), \( \beta \) denotes the sum of squared differences in between the coefficients of actual macro block and reconstructed macro blocks. On the other hand \( \gamma \) signifies the scalar multiplier and \( \theta \) denotes the required bit rates to transfer the estimated/transformed coefficients, motion vectors followed by motion compensation and
residuals once the encoding process is done. The study further modifies the initiation operations of AVC scheme and its inherent components to achieve superior performance efficiency in between the elastic mobility entities and transitional motion vectors. The following Table-4.1 highlights the notation used in the proposed algorithm of graph-based video compression.

Table 4.1 Highlights the notation used in the proposed algorithm of graph-based video compression.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Annotation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$M_b$</td>
<td>Micro block</td>
</tr>
<tr>
<td>2.</td>
<td>$Ref(F)$</td>
<td>Reference frame</td>
</tr>
<tr>
<td>3.</td>
<td>$TMV$</td>
<td>Transitional Motion Vector</td>
</tr>
<tr>
<td>4.</td>
<td>$R$</td>
<td>Rate</td>
</tr>
<tr>
<td>5.</td>
<td>$Dist$</td>
<td>Distortion</td>
</tr>
<tr>
<td>6.</td>
<td>$V_{matrix}$</td>
<td>Matrix to hold value</td>
</tr>
<tr>
<td>7.</td>
<td>$O_{CF}$</td>
<td>Optimum Compressed File</td>
</tr>
<tr>
<td>8.</td>
<td>$E$</td>
<td>Edges</td>
</tr>
<tr>
<td>9.</td>
<td>$V$</td>
<td>Varices</td>
</tr>
<tr>
<td>10.</td>
<td>$I$</td>
<td>Image</td>
</tr>
<tr>
<td>11.</td>
<td>$U$</td>
<td>Translation Motion Vector With least tree size</td>
</tr>
</tbody>
</table>

The proposed algorithm description is depicted below.

Algorithm One: Proposed Graph-based Video Compression using HEVC

Input: $M_b, Ref(F), TMV, r, Dist$

Output: $O_{CF}$

START

1. Initiate a Tree based structure of E,V
2. For ( unique($M_b$)$\leftarrow$32x32)
3. $InitRef(F)\rightarrow$Greyscale I
4. $U \leftarrow$ Compute min ($TMV|\gamma$) 
5. End of For
6. Estimate \( r, Dist \) for \( U \)
7. Apply Lagrangian coefficient measurement for all TMV & compute \( \alpha \)
   \[ \alpha = \beta + \gamma \]
8. IF(arg(\( \alpha \)) < TMV)
9. Estimate elastic motion compensation for \( u \).
10. ELSE
11. For (all_frames)
12. \( V_{matrix} \leftarrow \text{unique(frame_block)} \)
13. END
14. Update \( V_{matrix} \)
15. Compute \( PSNR, r, Dist \)

END

The above algorithm further simulated in a numerical computing platform on a 32 bit machine. However, the algorithm implementation has been carried out by means of standard Foremen dataset which is available in the web. The implementation process of the proposed graph-based compression protocol shows that it converts the RGB input video frames into greyscale to simplify the level of commutation. It further applies a linked investigational analysis subjected to identify the non-overlapping unique macro blocks. The proposed system also considers estimating the translation motion vectors with least size of the connectivity tree.

Further the algorithm also estimates the rate and distortion presence in frame sequence by applying RD-Theory. The concept of Lagrangian coefficient measurement (eq. 4.1) makes the computation of TMV and \( \alpha \) easier. Finally it checks the argument value of \( \alpha \), if it is found to be lesser than TMV then the process performs elastic motion compensation else it checks for the non-repetitive frame block sequences and update the matrix accordingly. The matrix is a data structure considered to hold the output value. Finally the proposed algorithm applies a quantization procedure on the block entities and the motion attributes to effectively measure the motion compensation from the frame registration process. It also evaluates tracking down motion objects to enhance the predictive analysis which required predicting future reference blocks along with motion compensation during encoding process.
4.6 COMPARATIVE ANALYSIS

The extensive experimental analysis of the proposed framework has been explicitly carried out in numerical computing platform. The proposed Graph Theory and RD-Theory based numerical concept has been validated in a prototyped test bed using performance parameters like Bitrate and PSNR. The following Figure 4.2 demonstrates the visual outcomes of the proposed study with its inherent performance metric. However, it also depicts how a macro block is segmented into various sizes of sub blocks.

![Figure 4.2 Visual outcomes of Graph-based HEVC Compression](image)

**Figure 4.2 Visual outcomes of Graph-based HEVC Compression**

The extensive performance analysis also shows the numerical outcomes obtained after simulating the Graph-based HEVC Compression in a parameterized platform.

![Figure 4.3 Performance Evaluation of the proposed method w.r.t bitrate](image)

**Figure 4.3 Performance Evaluation of the proposed method w.r.t bitrate**

The numerical outcomes are obtained from different level of encoding in STAGE-I the proposed study evaluates bit rate performance where, obtained results are compared with the work of Choi et al. [AR9]. Figure 4.3 shows that the proposed graph based compression attains performance efficiency with respect to bit rate and time as compared to
the Choi approach. In the STAGE-II, the experimental results are also compared with the conventional H.264/AVC and Choi approach in the following Figure 4.4.

![Graph showing bit rate performance evaluation](image1)

**Figure 4.4 Performance Evaluation of the proposed method w.r.t bit rate**

The experimental analysis also considers performance parameter like PSNR which is evaluated with respect to different bit rate. In STAGE-I the system performs evaluating PSNR with respect to 10Hz. Furthermore the outcomes obtained are plotted in Figure 4.5. Figure 4.6 also shows the outcomes attained with respect to video sequence of 15Hz. In this context the outcome of the proposed Graph based HEVC is thereby compared with the work of Choi et al. [58] as well as the integrated H.264.

![Graph showing PSNR performance evaluation](image2)

**Figure 4.5 Bit rate Performance Evaluation w.r.t PSNR video sequence 10Hz**

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The simulation outcome clearly depicts that our proposed approach attains high end video compression while maintaining superior visual aspects in the decoded video objects. It also shows the owing to the concept of Graph Theory and RD-Analysis the proposed compression scheme is found to be improved in terms of computational cost, PSNR and bitrate. Moreover, the extensive study also depicts the fact that if the number of encoding operation can be carried out on each block of frame recursively then it offers better resolution efficiency in the decoded video frames. A closer look into the outcome shows that the proposed model offers increase in the PSNR up to 0.7 dB while encoder operates on baseline architecture of HEVC. The analysis also exhibits that the proposed system processes the compression of heavier video object very faster (i.e. less than 0.65 s) while retaining higher perceptual quality at the receiver end.

4.7 CONCLUSION

The proposed study introduces a novel video compression algorithm on the top of conventional H.264 algorithm to achieve efficient compression efficiency along with reducing the cost of computation. The system evaluates the encoding process based on HEVC standard where Graph Based RD-Theory plays a crucial role to enhance the prediction of motion compensation. The study considers PSNR and bitrates as performance parameters. Moreover, the outcome of the study shows that it excel the performance of H.264 as well as conventional HEVC and ensure a better scope of implementation in futuristic video compression algorithms.