

A Nonlinear Analytical Approach for Video Compression in Telecommunication

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Abstract:

Introduction: The shift from analog to digital video has revolutionized communication by offering noise resistance, clarity, ease of transmission, and interactive user experiences. Digital video supports greater content capacity, catering to diverse viewer preferences and enhancing multimedia consumption. A nonlinear analytical approach for video compression techniques, such as transform coding, predictive coding, motion compensation, and entropy coding, play a vital role in applications like video conferencing and live streaming, enabling real-time transmission while efficiently utilizing network resources and storage. The integration of these technologies fosters a dynamic, high-quality multimedia ecosystem

Objectives: Research and development in nonlinear video compression objectives focus on reducing video file sizes without compromising quality by leveraging redundancies and characteristics of video data. This is vital objectives for applications like video streaming, conferencing, digital television, and multimedia distribution, driving improvements in storage efficiency, bandwidth utilization, and user experience.

Methods: Existing methodologies for block matching motion estimation, such as FS, TSS, NTSS, DS, and ETSS, have shown limitations in video compression. To address this, a novel "Nonlinear approach" combining the Hexagonal Search (HS) and Efficient Three Step Search (ETSS) algorithms has been proposed. This technique aims to reduce redundancy, minimize search points, and improve video compression efficiency. It also delves into the complexities of motion estimation and compensation, providing insights from the conceptualization of video sequences to the implementation of motion-compensated coding techniques.

Results: All the parameters such as Sum of Absolute Difference (SAD), Mean of Absolute Difference (MAD), Mean Square Error (MSE), Peak-Signal to Noise Ratio (PSNR) and Compression Ratio are applied for the statistical performance study. Nonlinear approach gives appreciable results as compared with the existing methodologies. Video quality as also assessed through various nonlinear compression techniques give better results.

Conclusions: A Nonlinear approach to block matching motion estimation has been introduced, integrating the strengths of Efficient Three-Step Search (ETSS) and Hexagonal Search (HS). This method delivers superior results while requiring fewer search points than traditional algorithms such as TSS, FS, NTSS, and 4SS. Hexagonal Search (HS) also outperforms Diamond Search (DS) and Cross Diamond Search (CDS) in efficiency. Rigorous testing using the Akiyo.avi standard database confirms the Nonlinear approach's

effectiveness, particularly in reducing computational complexity, making it a more advanced motion compensation technique compared to ETSS.

Keywords: High quality video compression, video transmission, nonlinear approach image process.

1. Introduction

Video compression is essential for reducing the size of video files, making them more manageable for storage, transmission, and streaming. As you mentioned, videos are essentially a collection of consecutive frames displayed in a sequence. Redundancy in video data arises because adjacent frames often share similarities, and there may be areas of the frame that don't change much over time.

Video compression techniques aim to exploit these redundancies and reduce the amount of data needed to represent the video while preserving its quality to an acceptable extent. There are two main types of video compression: lossless and lossy. These compression techniques allow for efficient storage and transmission of videos, making them accessible to a broader audience with varying network conditions and storage capabilities.

In the dynamic landscape of telecommunication networks, where resources are often constrained, the implementation of effective video compression techniques stands as a critical necessity. This strategic approach not only ensures the delivery of high-quality multimedia content but also plays a pivotal role in mitigating the impact on limited network resources. The inevitable shift from analog to digital video represents a monumental leap in the evolution of video communication. The advantages bestowed by digitization are manifold. Digital video, characterized by its virtual immunity to noise, emerges as a resilient medium, offering unparalleled clarity and reliability. Its inherent ease of transmission further contributes to a seamless and efficient network experience. Digital video provides a more interactive and engaging platform for users, fostering an immersive viewing experience. This enhancement in user interaction is a testament to the technological strides enabled by the digital era.

Moreover, the transition to digital formats brings about a substantial increase in content capacity. This not only broadens the spectrum of available content but also caters to diverse viewer preferences. As the demand for dynamic communication experiences continues to surge, the integration of moving video pictures becomes paramount. In conclusion, the symbiosis of effective video compression and digitization not only optimizes resource utilization in telecommunication networks but also paves the way for an era where high-quality multimedia content is not just consumed but actively shaped and shared by end-users across diverse communication platforms. Telecommunication networks have limited bandwidth. Video compression saves the amount of data for the representation of a video, enabling efficient use of available bandwidth. Compressed videos require less storage space, making it more feasible for storage and transmission over telecommunication networks. Video compression allows for the real-time transmission of video content, which is crucial for applications such as video conferencing and live streaming. Transform coding, predictive coding, motion compensation, entropy coding are the common video compression techniques are available in telecommunication system.

2. Objectives

The main driving force behind research and development in video compression is the necessity to reduce the size of video data. The challenge in video compression lies in finding methodologies and techniques that can significantly decrease the size of video files without sacrificing perceptual quality. This involves developing algorithms that exploit redundancies and other characteristics inherent in video data, allowing for more efficient encoding and decoding processes. Overall, video compression plays a crucial role in various applications such as video streaming, video conferencing, digital television, and multimedia content distribution. Advancements in this field have led to significant improvements in storage efficiency, bandwidth utilization, and overall user experience in consuming video content.

Historically, the quest for efficient video compression techniques has been a central focus of research activities since the early 1980s. Over the years, research has delved into refining algorithms, with notable strides made in areas like motion estimation. From the early 2000s onward, initiatives such as MPEG-7 and MPEG-21 have emerged, reflecting an evolving emphasis on not just compressing video data but also enhancing the ability to efficiently search and retrieve relevant content. In essence, the motivation driving the relentless pursuit of advancements in video compression lies in the ever-growing demand for streamlined storage, rapid transmission, and enhanced accessibility of video content. The objective of the work was to develop a mechanism on video compression based on Block matching motion estimation Algorithm.

3. Methods

Block Matching Motion Estimation with video Coding for Telecommunication

An examination revealed that existing methodologies, including FS, TSS, NTSS, DS, and ETSS, yielded unsatisfactory results in block matching motion estimation for video compression. In response, we introduce a novel technique, a fusion of the Hexagonal Search algorithm (HS) and the Efficient Three Step Search algorithm (ETSS), termed the "Nonlinear Approach" or "Nonlinear approach Technology." The primary advantage of employing video compression is its ability to minimize disk space utilization and accelerate file transfer rates. Through this block matching motion estimation approach, we aim to innovate and enhance video features, focusing on reducing redundancy and the number of search points. Here, we have discussed comprehensive overview of the complexities involved in motion estimation and compensation in video processing systems. It covers various aspects from the conceptualization of video sequences to the practical implementation of motion-compensated coding techniques.

Conceptualization of Video Sequences: Videos can be seen as discrete representations of the continuous four-dimensional space-time. They capture the movements, rotations, and deformations of objects over time. **Perception of Dynamics:** Dynamics such as object movements, rotations, and deformations are perceived through the reflection of light from object surfaces onto an image. Various factors like the motion of the light source, object occlusions, shadows, transparency, and atmospheric conditions can affect the observed image. **Introduction of Noise:** The discretization of video sequences introduces noise, which can impact motion estimations made by video encoders. This noise can come from sources such as the image capture device (camera) and electrical transmission lines.

Motion Estimation (ME): Video encoders use a model of object motion between frames to estimate the motion occurring between a reference frame and the current frame. This process, known as motion estimation, is crucial for predicting frame-to-frame changes accurately. **Motion Compensation (MC):** With the motion model obtained from estimation, the encoder employs motion compensation to adjust the contents of the reference frame. This adjustment aims to provide a more accurate prediction of the current frame, reducing redundancy and improving compression efficiency. **Motion-Compensated Prediction (MCP):** The process of adjusting the reference frame to predict the current frame accurately is referred to as motion-compensated prediction or displaced-frame. **Displaced-Frame Difference (DFD):** The difference between the predicted frame and the actual frame, after motion compensation, is termed the displaced-frame difference. It represents the prediction error signal. **Interframe Coding Method:** A block diagram of a motion-compensated coding system is illustrated in figure 1, representing the most commonly used interframe coding method. This method utilizes motion estimation and compensation techniques to efficiently code video sequences.

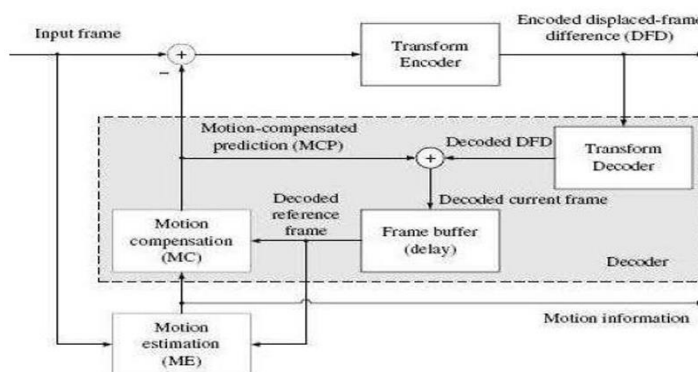


FIGURE 1. Video Coding for Motion Compensation and Estimation

4. Results

Performance Metrics Relevant to Telecommunication

The various statistical performance metrics are applied relevant to telecommunication domain such as Sum of Absolute Difference (SAD), Mean of Absolute Difference (MAD), Mean Square Error (MSE), Peak-Signal to Noise Ratio (PSNR) and Compression Ratio.

Dataset Selection for Telecommunication Networks

First RGB frames are taken out of video and then converted into YCbCr and then to Gray as shown and then quad tree partitioning is applied on it. Nonlinear approach Block matching motion estimation algorithm is applied to find motion vector. And its result are shown in terms matching criteria's SAD and MAD. Fractal encoding and decoding techniques are applied on it. After decoding Reconstructed frames are obtained and are shown below. Mean square error (MSE) and Peak Signal to Noise ratio (PSNR) are also shown in graphs. SAD and MAD comparison between ETSS and Nonlinear approach (ETSS+HS) is shown. And we can clearly see that Nonlinear approach gives better result as compared to ETSS. It takes less search points as compared to ETSS. It almost reduced to half. Experimentation is carried out on different sample Test videos: 1) Akiyo_cif.avi, 2) Suzie.avi, 3) Flower.avi, 4) Bus.avi, 5) Football.avi, 6) Soccer.avi, 7) Mobile.avi. Figure 4 shows the input image conversion to YCbCr and Gray frames and Video frames Quadtree partition and final reconstructed frames.

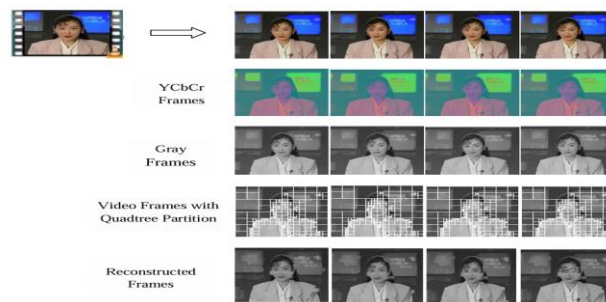


FIGURE 4. Input image conversion to YCbCr and Gray frames and Video frames Quadtree partition and final reconstructed frames

Compression Ratios in Telecommunication Networks

Compression Ratio obtained for different databases are shown in table 1. and average search point taken to estimate the motion by ETSS and HS are given separately.

TABLE 1. Compression ratio & average search point (ETSS+HS) of Test video

Sr. No.	Test video	Compression ratio %	Average search point (ETSS) 10^{-3}	Average search point (HS) 10^{-3}
1	Akiyo_cif.avi	61.03%	0.47446	0.43613
2	Suzie.avi	08.08%	0.54557	0.59852
3	Flower_cif.avi	70.52%	0.56265	0.73177
4	Bus.avi	13.46%	0.61383	0.71105
5	Football.avi	74.48%	0.58963	0.64227
6	Soccer.avi	06.73%	0.61427	0.63922
7	Mobile_cif.avi	60.47%	0.52232	0.59966

Video Quality Assessment for Telecommunication

Video Quality Assessment is performed by PSNR and MSE parameters shown in Table 2.

TABLE 2. PSNR and MSE for different video frames

Sr. no	Test video	PSNR(db)	MSE
1	Akiyo_cif.avi	21.76	0.1082
2	Suzie.avi	17.73	0.2732
3	Flower_cif.avi	10.55	0.0014
4	Bus.avi	9.15	0.0095
5	Football.avi	10.17	0.0015
6	Soccer.avi	12.21	0.7091
7	Mobile_cif.avi	8.17	0.0058

5. Discussion

This research paper aims to provide insights into a Nonlinear approach for video compression, specifically designed for telecommunication applications. Introducing a Nonlinear approach to block matching motion estimation, our method combines the strengths of Efficient Three-Step Search (ETSS) and Hexagonal Search (HS). Notably, our Nonlinear approach algorithm not only yields superior results but also demands fewer search points compared to Traditional Three Step Search (TSS), Full Search (FS), New Three Step Search (NTSS), and 4SS. In the realm of search algorithms, Hexagonal Search (HS) outperforms Diamond Search (DS) and Cross Diamond Search (CDS), presenting a more effective solution. Rigorous experimentation unfolds on the Akiyo.avi standard database, affirming the supremacy of our Nonlinear approach Motion Compensation technique over the esteemed ETSS method, particularly in terms of computational complexity.

Looking ahead, there remains ample room for advancements in crafting a novel block matching motion estimation paradigm. A promising avenue involves amalgamating diverse existing algorithms in the realm of block matching motion estimation, the holistic strategy aims to propel efficiency in the compression domain, laying the groundwork for more streamlined and time-effective video processing methodologies in the future.

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