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Variable-Length Entropy Coding of Video Transmission in WLAN

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ABSTRACT: Conventional video compression relies on interframe prediction (motion estimation), intraframe prediction, and variable-length entropy encoding to achieve high compression ratios but, as a consequence, produces an encoded bit stream that is inherently sensitive to channel errors. In order to ensure reliable delivery over lossy channels, it is necessary to invoke various additional error detection and correction methods. In contrast, techniques such as pyramid vector quantization (PVQ) have the ability to prevent error propagation through the use of fixed-length code words. This paper introduces an efficient rate-distortion optimization algorithm for intramode PVQ, which offers similar compression performance to intra H.264/AVC and Motion JPEG 2000, while offering inherent error resilience.

The performance of our enhanced codec is evaluated for high definition content in the context of a realistic (IEEE 802.11n) wireless environment with up to 11 dB PNR improvement over H.264/AVC. We show that PVQ provides greater tolerance to corrupted data while obviating the need for complex encoding tools.

I.INTRODUCTION

THE prevalence of high-definition (HD) cameras, televisions, Blu-Ray players, and DVD recorders means that almost all video content is now captured and recorded digitally and much of it in HD. Compression is an essential component in a digital video system and is required to ensure manageable transmitted bitrates and storage. MPEG-2, H.264/AVC, and VC-1 are the most popular codes in use today, and these rely on decorrelating transforms, motion estimation, intra prediction, and variable-length entropy coding (VLC) to achieve good picture quality at high compression ratios .[1]

Alongside the need for efficient video compression, there is a critical requirement for error resilience, in particular in association with wireless networks which are characterized by highly dynamic variations in error rate and bandwidth .A topical example where error resilience is important is in home HDTV video transmission using wireless technology. Wireless HD wireless high-definition interface (WHDI) and AXAR Media represent some of the commercial solutions available.

Wireless HD allows uncompressed HD video to be transmitted in the 60-GHz band but is limited to in-room use only. WHDI utilizes proprietary video compression techniques before transmitting in the unlicensed 5-GHz band. AXAR employs H.264/AVC to compress the video before transmitting it robustly over standard IEEE 802.11n wireless networks. All of these systems support at least 30 Mb/s of usable bit rate at the application layer.[3]

Other important application areas include military and surveillance systems where quality and latency are also of paramount importance. It is well known that compression techniques based on prediction and variable-length coding render an encoded bit stream highly sensitive to channel errors. Error-resilient techniques based on redundant slices, data partitioning, flexible macro block ordering (FMO) and intra refresh alongside forward error correction (FEC) and automatic repeat request are frequently employed to make the compressed bit stream more resilient.[2]

Using fixed-length codes (FLCs) can also improve error resilience, but these are not supported in codes such as H.264/AVC, VC-1 or MPEG-2 .Pyramid vector quantization (PVQ), introduced by Fischer as an optimal vector

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quantization encoding technique for Laplacian random variables, has the advantage of producing fixed-length code words. In it was shown that transform coefficients have Laplacian-like probability distributions and hence PVQ is an efficient means of compressing them. Error-resilient image and video coding using PVQ was investigated in where it was shown that PVQ is much more resilient to bit errors than either JPEG or H.263. It was also shown that wavelet-based PVQ outperforms DCT-based PVQ in terms of compression performance.

we showed that intra mode PVQ is an Meffective codec for indoor wireless transmission of HD video. Intra mode coding was employed since interframe encoding can lead to temporal error propagation. Although there is a loss in compression performance due to using an intra-only mode, this is more than compensated for by the increased error resilience. Video optimized multiple input–multiple output (MIMO) WLANs based on IEEE 802.11n are now able to provide the source throughput required by HD intra only codes.

This paper presents two contributions. First, it introduces an efficient rate-distortion (RD) algorithm for PVQ which yields impressive compression performance. The performance of the codec is shown to be comparable to intra-H.264/AVC and Motion JPEG 2000. Second, the error resilience of the code is evaluated in the context of a realistic lossy wireless channel, allowing us to characterize the superior performance of the approach.

This paper is organized as follows describes the wavelet-based PVQ encoder and the new RD-optimized compression algorithm. compares the compression performance of intra-PVQ with intra-H.264/AVC and Motion JPEG 2000. compares the error resilience of intra-PVQ with intra-H.264/AVC in an indoor MIMO WLAN scenario.

II.SCALAR QUANTIZATION

Uniform Quantization

The simplest way to do uniform quantization is by dividing the signal to be quantized with the step size and then round to an integer. If we only want a limited number of intervals, the resulting integer sequence should then be thresholded, but this is not necessary for all applications. Reconstruction is done by multiplying the integer sequence with the step size.[4]

For a limited number of quantization steps, try the function unquant. The number of quantization levels given will determine the type of quantization. An odd number of levels gives a midtread quantizer, while an even number gives a midrise quantizer.

For fine uniform quantization, the distortion is approximately $D=\Delta^2/12$ where Δ is the step size of the uniform quantizer. Check how good this approximation is by quantizing data with different step-sizes and number of levels and calculate the resulting distortion. Suitable data to quantize can be random gaussian data (from the Matlab function randn) is reasonable. For each choice of the number of levels, determine which choice of step size that gives the lowest distortion.

III.VECTOR QUANTIZATION

Vector quantization can obtain better results, and an intuitive version of it is described here. The image is partitioned into equal-size blocks (called *vectors*) of pixels, and the encoder has a list (called a *codebook*) of blocks of the same size. Each image block B is compared to all the blocks of the codebook and is matched with the “closest” one. If B is matched with codebook block C , then the encoder writes a pointer to C on the compressed stream. If the pointer is smaller than the block size, compression is achieved.

According to Shannon's rate distortion theory, better results are always obtained when vectors rather than scalars are quantized. Developed by Gersho and Gray in 1980, vector quantization has proven to be a powerful tool for digital image compression

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The method is encoding a sequence of samples (vectors) rather than encoding each sample individually. Encoding is performed by approximating the sequence to be coded by a vector belonging to a catalogue of shape, usually known as a codebook or dictionary. [5]

The codebook consists of code vectors. The number of code vectors in the codebook is given by 2^{RL} , where R is rate or bits per pixel (bpp) and L is the dimension.

IV.PYRAMID VECTOR QUANTIZATION

Pyramid vector quantization (PVQ) was introduced by Fischer as a fast and efficient method of quantizing Laplacian-like data, such as generated by transforms or sub band filters in an image compression system. PVQ has very simple systematic encoding and decoding algorithms and does not require significant codebook storage. It combines the robustness of fixed-rate codes with the performance of entropy-coded scalar quantization. Considerable research in PVQ algorithms has culminated in high performance, error resilient PVQ image compression systems for both transforms and sub band decompositions. PVQ has also been implemented in hardware, taking advantage of a computationally constructed codebook instead of a stored codebook to build a robust, low power, video rate PVQ decoder.[7]

There are new ways of assigning indices to the points in the PVQ codebook that improves channel robustness by up to 3 dB over previous enumerations, and up to 6 dB over a randomly enumerated codebook.[8] These new indexing techniques require roughly the same encoding and decoding hardware complexity as previous enumerations and can be applied to any of the fixed rate PVQ coding systems described previously in the literature. We discuss the theoretical and simulated advantage of new techniques through channel noise models of the PVQ indices and codebooks. Finally, we show the practical advantages of PVQ by demonstrating an error-resilient PVQ system that exceeds the performance of Joint Photographic Experts Group (JPEG) implementations, both with and without channel error.

The PVQ-encoded bit stream comprises a sequence of codebook vector indices. These can be generated using techniques such as magnitude enumeration, linear enumeration, conditional product code enumeration, or conditional product– product code enumeration. The application areas include military and surveillance systems where quality and latency are also of paramount importance.[9]

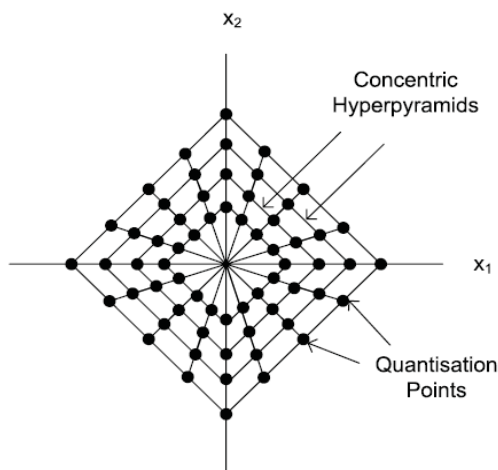


Fig. 1. Example product code PVQ structure for $L = 2$.

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Algorithm for Pyramidal Vector Quantization

The process of pyramidal vector quantization involves the following steps and the algorithm for pyramidal vector quantization can be listed as

1. All the vectors (having dimension of L) taken from the wavelet-transformed images (sub-band images) are projected on the surface of the pyramid $S\left(L, \frac{L}{\lambda}\right)$ such that the projection yields the least mean squared error.

All the Vectors lying on the surface of the pyramid $S\left(L, \frac{L}{\lambda}\right)$ have a norm of $\frac{L}{\lambda}$.

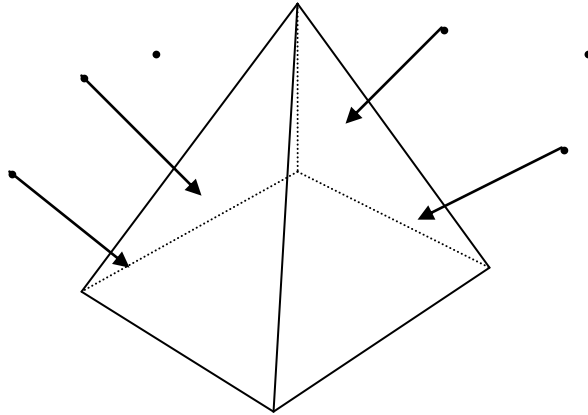


Figure 3.1. Projection of vectors on the surface of the pyramid $S\left(L, \frac{L}{\lambda}\right)$

2. The black dots in space represent the vectors taken from the sub-band images with a dimension of L. These vectors are projected on the surface of the pyramid $S\left(L, \frac{L}{\lambda}\right)$ with least MSE. The main outcome of this projection is that, the dynamic range of the actual vectors is decreased, but produces least distortion.
3. The vectors lying on the surface of the pyramid $S\left(L, \frac{L}{\lambda}\right)$ are then scaled to an inner pyramid $S(L, K)$ with a scaling factor of Υ where the inner pyramid $S(L, K)$ is chosen based on the rate criterion 'R' bits/dimension.

Pyramid vector quantization has been previously used for DCT and sub band image compression because both the sub band and transformed image data are similar to the Laplacian in distribution. PVQ also has been considered in the context of matched joint source-channel coding for images, where the channel statistics are stationary and known. The following three sections demonstrate the advantages of the new error-resilient PVQ coding schemes introduced here for sub band image compression under varying channel conditions.[10]

The pyramid vector quantizer, by itself, assigns points to the nearest code word on a single pyramid shell. For image compression applications where the vector lengths are small, the pyramid vector quantizer is typically matched with a radial quantizer to form several concentric pyramid shells. This is called polar or product quantization, where the radius is quantized independently from the position on the shell.[11]

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Pyramid vector quantization utilizes four steps to code an input vector into digital bits.

- The first step is to find the nearest pyramid shell to the input vector.
- The second step is to scale the point onto the cubic lattice.
- The third step is to round the point to the nearest point in the cubic lattice that is on the pyramid shell.[12]
- The fourth step is to enumerate that cubic lattice point, a process which assigns a unique index to each point on the pyramid shell.

PVQ provides excellent video quality on sequences with significant texture and motion, such as *Riverbed* and *Pedestrian Area*. This is significant, as the quality of HD compression is often judged by its ability to handle texture and motion, where coding artifacts can be visually disturbing. During transmission, each slice is passed to the physical layer where it is divided into packets, where each packet is independently sent and received. The number of packets PER slice depends on both the slice size and packet size PVQ codec offers a low-complexity implementation. since it obviates the need for sophisticated encoding prediction, motion estimation, variable size transforms, deblocking filters, or context-adaptive bit encoding.[17].

V.RESULT ANALYSIS

The blocks are connected and simulation has to be done. The video input is converted into frames. Each frame is given the sampling rate and decomposed into two sub bands (high frequency and low frequency). The output is down sampled and it is quantized.

As the simulation starts, the rate of each frame is varied according to the sampling rate and frequency. The varied frames are encoded and it is displayed. Thus the performance of each frame in the video is determined and it is observed accurately.

The image compression technique based on wavelet packet transform and pyramidal vector quantization is found to perform well with compression ratio and good PSNR values in the range of 20-40 db. The performance of the proposed scheme was seen to be competitive with that of the state of the art coders in terms of PSNR and Compression ratio.[15]

VI.CONCLUSION

This paper has shown that PVQ is a serious contender for future wireless video transmission systems, particularly for in-home and surveillance applications. We have demonstrated the merits of PVQ as an alternative to H.264/AVC and Motion JPEG 2000 for robust HD video coding over error prone wireless channels.

The design and implementation of an RD-optimized compression algorithm for intramode HD PVQ video encoding has been presented. This guarantees selection of the optimal set of PVQ encoding parameters which minimize the distortion at a given target bit rate.[13] PVQ is observed to give excellent video quality in intra mode at or above 25 Mb/s for 1080p (43 dB PSNR) and to provide comparable compression performance to H.264/AVC (intra) and Motion JPEG 2000 across a range of representative sequences. [14]

PVQ also has significant computational advantages over H.264/AVC and Motion JPEG 2000, as it does not require sophisticated encoding tools such as intra prediction modes, motion estimation, variable size transforms, deblocking filters, or context-adaptive bit encoding algorithms. In terms of error resilience, PVQ (without explicit error resilience tools and without error concealment) has been shown to outperform H.264/AVC (with FMO, slice modes, and error concealment) under a variety of channel, modulation, and coding conditions. For uncorrelated errors, at constant compression bitrates, PVQ offers up to 13.3 dB PSNR performance gain over the best performing H.264/AVC counterpart. Even in the case of highly correlated errors, our PVQ codec exhibits up to 11.3 dB PSNR improvement over the best performing H.264/AVC counterpart. PVQ is able to outperform other codes because of its use of fixed-length coding. This enables the PVQ decoder to extract the maximum Utility from corrupted packets.[16]

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VII.FUTURE WORK

A systematic work of PVQ decoder has to be designed for evaluating the performance in case of retrieving the original image and the error rate. PVQ decoder provides better improvement and is used to find the performance evaluation in terms of their distortion rate.

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