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Impact of various profiles of H.264 video codec on its performance

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Abstract
This paper investigates the effects of profiles of H.264 video codec on its performance. H.264 is the latest international video coding standard. It was jointly developed by the video coding expert group (VCEG) of the ITUT and moving picture expert group (MPEG) of ISO/IEC. The main goals of the H.264 standardization effort have been enhanced compression performance. H.264 has achieved a significant improvement in rate distortion efficiency relative to existing standards. It uses state of the art coding tools and provide enhanced coding efficiency for a wide range of applications including video telephony, video conferencing, streaming video, digital video authority, digital cinema and many others.

Keywords: Baseline profile, main profile, extended profile, Peak Signal to Noise ratio.

1. Introduction

1.1 Overview of H.264 Video Codec

Schematic of a typical video encoder is shown in Figure 1. The encoder changes the data into a compressed form proceeding to storage or transmission and the decoder converts the compacted or compressed form back into a representation of the original video data. The combination encoder/decoder pair is also called as a CODEC (enCOder/ DECoder) [1, 2].

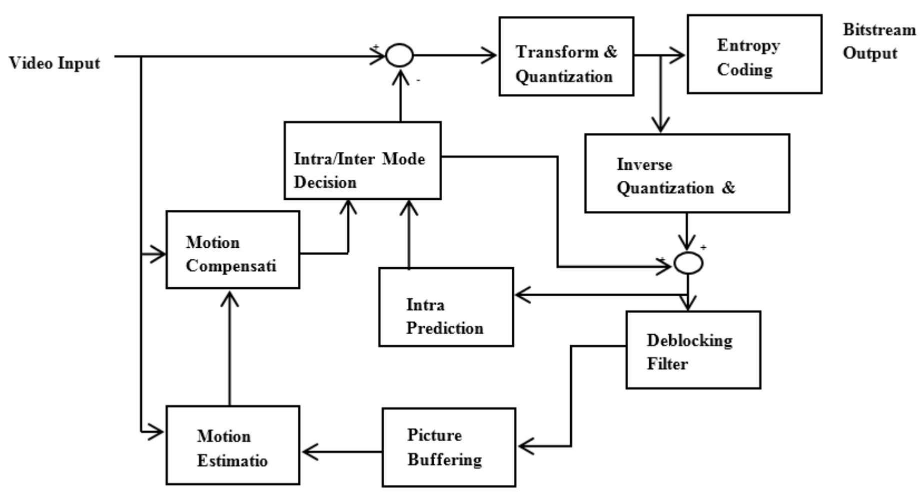

Fig 1: Block diagram of H.264/AVC encoder.

The error resilience technique enables the compressed bit-stream to resist channel errors so that the impact on the reconstructed image quality should be as minimum as possible.
Error resilience takes nearly 20% of the consumption [3, 4].

2. Overview of Various Profiles

While H.264/ AVC standard contains a rich set of video coding tools, not all the coding tools are required for all applications. For example, error resilience tools may not be needed for video stored on a compact disk or on networks with very few errors. Therefore, the standard defines subsets of coding tools intended for different classes of applications. These subsets are called profiles. There are three profiles in the first version: baseline (BP), main (MP), and extended (XP) [5]. Baseline profile is to be applicable to real-time conversational services such as video conferencing and videophone. Main profile is designed for digital storage media and television broadcasting. Extended profile is aimed at multimedia services over Internet. Also there are four high profiles defined in the fidelity range extensions for applications such as content contribution, content-distribution and studio editing and post-processing: High (Hi), High 10 (Hi10), High 4:2:2 (Hi422) and High 4:4:4 (Hi444).

High profile is to support the 8-bit video with 4:2:0 sampling for applications using high resolution. High 10 profile is to support the 4:2:0 sampling with up to 10 bits of representation accuracy per sample. High 4:2:2 profile is to support up to 4:2:2 chroma sampling and up to 10 bits per sample. High 4:4:4 profile is to support up to 4:4:4 Chroma sampling, up to 12 bits per sample and integer residual color transform for coding RGB signal. Table shows the features supports in different profiles [5, 6].

Table 1: Features of different profiles of H.264.

Feature	BP	MP	XP
B Slices	No	Yes	Yes
SI and SP Slices	No	No	Yes
Flexible Macroblock Ordering (FMO)	Yes	No	Yes
Data Partitioning	No	No	Yes
Interlaced Coding	No	Yes	Yes
CABAC Entropy Coding	No	Yes	No
8×8 vs. 4×4 transform adaptivity	No	No	No
Quantization Scaling Matrices	No	No	No
Separate C_b and C_r QP Control	No	No	No
Monochrome(4:0:0)	No	No	No
Chroma Formats	4:2:0	4:2:0	4:2:0
Sample Depths (bits)	8	8	8

3. H.264/Avc Profiles and Corresponding Tools

These constraints may be simple limits on values or alternatively they may take the form of constraints on arithmetic combinations of values (e.g. picture width multiplied by picture height multiplied by number of pictures decoded per second) [8]. In H.264/AVC, the same level definitions are used for all profiles defined. However, if a certain terminal supports more than one profile, there is no obligation that the same level is supported for the various profiles. A profile and level combination specifies the so-called conformance points, this means points of interoperability for applications with similar functional requirements. Summing up, profiles and levels together specify restrictions on the bit streams and thus minimum bounds on the decoding capabilities, making possible to implement decoders with different limited complexity, targeting different application domains. Encoders are not required to make use of any specific set of tools; they only have to produce bit streams which are compliant to the relevant profile and level combination. To address the large range of applications considered by H.264/AVC, three profiles have been defined (see Figure 2).

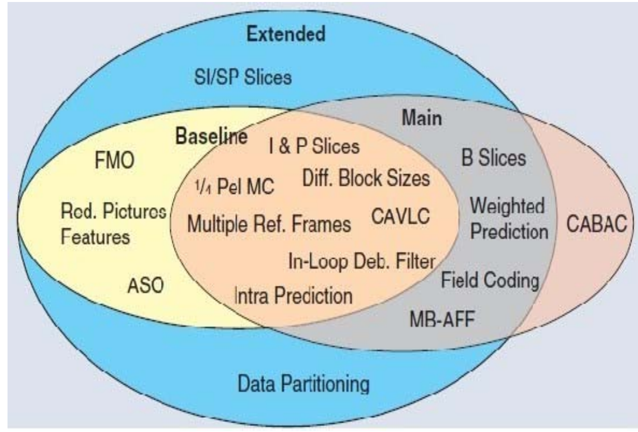

Fig 2: H.264/AVC profiles and corresponding tools (5).

From Figure 2, it is clear that there is a set of tools supported by all profiles but the hierarchical capabilities for this set of profiles are reduced to Extended being a superset of Baseline. This means, for example, that only certain Baseline compliant streams may be decoded by a decoder compliant with the Main profile. Although it is difficult to establish a strong relation between profiles and applications (and clearly nothing is normative in this regard), it is possible to say that conversational services will typically use the Baseline profile, entertainment services the Main profile, and streaming services the Baseline or Extended profiles for wireless or wired environments, respectively. However, a different approach may be adopted and, for sure, may change in time as additional complexity will become more acceptable. In H.264/AVC, 15 levels are specified for each profile. Each level specifies upper bounds for the bit stream or lower bounds for the decoder capabilities, e.g., in terms of picture size (from QCIF to above 4k×2k), decoder processing rate (from 1485 to 983040 macroblocks per second), size of the memory for multi-picture buffers, video bit rate (from 64 kbit/s to 240 Mbit/s), and motion vector range (from [−64, +63.75] to [−512, +511.75]). For more detailed information on the H.264/AVC profiles and levels.

4. H.264 Profiles and Their Impact on Performance of H.264/Avc

4.1 Baseline Profile

4.1.1 Arbitrary Slice Ordering

Arbitrary slice ordering allows the decoder to process slices in an arbitrary order as they arrive to the decoder. Hence the decoder does not have to wait for all the slices to be properly arranged before it starts processing them. This reduces the processing delay at the decoder, resulting in less overall latency in real-time video communication applications.

4.1.2 Flexible Macroblock Ordering (FMO)

Macroblocks in a given frame are usually coded in a raster scan order. With FMO, macroblocks are coded according to a macroblock allocation map that groups, within a given slice, macroblocks from spatially different locations in the frame. Such an arrangement enhances error resilience in the coded bit stream since it reduces the interdependency that would otherwise exist in coding data within adjacent macroblocks in a given frame. In the case of packet loss, the loss is scattered throughout the picture and can be easily concealed.

4.1.3 Redundant Slices
Redundant slices allow the transmission of duplicate slices over error-prone networks to increase the likelihood of the delivery of a slice that is free of errors.

4.2 Main Profile
4.2.1 B Pictures
B-pictures provide a compression advantage as compared to P-pictures by allowing a larger number of prediction modes for each macroblock. Here, the prediction is formed by averaging the sample values in two reference blocks, generally, but not necessarily using one reference block that is forward in time and one that is backward in time with respect to the current picture. In addition, "Direct Mode" prediction is supported, in which the motion vectors for the macroblock are interpolated based on the motion vectors used for coding the co-located macroblock in a nearby reference frame. Thus, no motion information is transmitted. By allowing so many prediction modes, the prediction accuracy is improved, often reducing the bit rate by 5-10%.

4.2.2 Weighted Prediction
This allows the modification of motion compensated sample intensities using a global multiplier and a global offset. The multiplier and offset may be explicitly sent, or implicitly inferred. The use of the multiplier and the offset aims at reducing the prediction residuals due, for example, to global changes in brightness, and consequently, leads to enhanced coding efficiency for sequences with fades, lighting changes, and other special effects.

4.2.3 CABAC
Context Adaptive Binary Arithmetic Coding (CABAC) makes use of a probability model at both the encoder and decoder for all the syntax elements (transform coefficients, motion vectors, etc). To increase the coding efficiency of arithmetic coding, the underlying probability model is adapted to the changing statistics within a video frame, through a process called context modeling. The context modeling provides estimates of conditional probabilities of the coding symbols. Utilizing suitable context models, given inter-symbol redundancy can be exploited by switching between different probability models according to already coded symbols in the neighborhood of the current symbol to encode. The context modeling is responsible for most of CABAC's 10% savings in bit rate over the VLC entropy coding method (UVLC/CAVLC).

4.2.4 Interlace Support
Interlaced video has two half pictures (fields) in a frame or full picture and they are at different times. The Main profile copes with this by supporting field coding and picture or macroblock adaptive switching between frame and field coding.

4.3 Extended Profile
This profile supports all features of the Baseline profile, with the addition of B slices, weighted prediction, field coding and picture or macroblock adaptive switching between frame and field coding. Furthermore it is the only profile to support the SP/SI slice data portioning. It does not support CABAC. The context modeling is responsible for most of CABAC's 10% savings in bit rate over the VLC entropy coding method (UVLC/CAVLC).

5. Conclusion
When we analyze the impact of various profiles on H.264/AVC, it is found that in baseline profile three properties of coder Arbitrary Slice Ordering, Flexible Macro block Ordering (FMO) and Redundant Slices are mainly effected.
For main profile weighted predictions, B-pictures, context adaptive binary arithmetic coding and interlace support properties are mainly effected. The context modeling is responsible for most of CABAC's 10% savings in bit rate over the VLC entropy coding method (UVLC/CAVLC).

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