Compression Standard MPEG-4 AVC (Advanced Video Coding)

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Abstract. *This letter deals with the basic principles and functions of the new compression standard MPEG-4 AVC, which has been developed for an effective compression of the digital video data; for digital signals of the high definition television (HDTV) especially.*

Keywords

Video compression, encoder, algorithm, television technology, profile, level, sampling format.

1. Introduction

The standard MPEG-4 AVC, called also MPEG-4 Part 10 (by the ITU H.264) is a digital video compression standard, which has arisen as the collective product of the ITU-T VCEG (Video Coding Experts Group) and ISO/IEC MPEG (Moving Coding Experts Group). It is described by the norm ISO/IEC 14496-10 (2003).

The standard utilization is presently growing due to the start of the HDTV (High Definition TV). HDTV technology requires considerably larger video bit-rate – about 4 Mbit/s for the standard resolution PAL 576 × 720 pixels, and about 18 Mbit/s for HD resolution 1080 × 720 pixels (progressive). Application of HDTV requires an employment of a more effective compression algorithm compared to the present compression algorithm (standard) MPEG-2 (by the ITU H.262).

Research performed by French experts is the leading one in Europe. The French research is aimed to replace the standard MPEG-2 by the MPEG-4 AVC in contemporary digital terrestrial broadcasting DVB-T with the standard resolution (PAL). These perspectives influence some experts and providers of digital broadcasting in France. Purchasers of the current set top boxes for DVB-T are flustered, since a new product with the embedded MPEG-4 AVC decoder or with both ones will be needed later.

The new compression standard was proposed for the large function variability. Its parameters are very flexible. The standard can be applied to a very wide variety of applications – for both high and low bit rates, for various sampling formats. Dominantly, the standard is destined for the digital broadcasting DVB-T, DVB-H, the digital storage of video data (standard DVD or HD DVD, Blue-ray Disc and others), for the multimedia distributive networks (ADSL2+, VDSL, e.g.) and other applications. The MPEG-4 AVC standard is based on basic principles of the MPEG-2 standard, whose parameters are qualitatively and quantitatively improved so that the average compression factor is twice enhanced (in case of the MP profile). The MPEG-4 AVC encoder and decoder are very complicated due to the sophisticated principles of the compression. Integrated processors supporting both MPEG-2 and MPEG-4 AVC compression algorithms are produced presently (the circuit Broadcom BCM 7411, e.g.). A detailed description of the MPEG-4 AVC compression standard is out of the scope of this letter. Therefore, only the basic properties and parameters will be described here.

Notice 1: In parallel to the MPEG-4 AVC algorithm, the video compression algorithm **MPEG-4 Part 2** (sometimes MPEG-4 Visual) was proposed by the **ITU H.263.** This algorithm is of the object-oriented nature, and used in computer techniques. Principles of this compression algorithm are considerably different from those of the MPEG-4 AVC one.

2. Basic Parameters of the MPEG-4 AVC Standard

The main improvements used in the MPEG-4 AVC standard compared to the MPEG-2 one:

- **VBSMC** (Variable Block Size Motion Compensation) for precise segmentation of moving areas (from 4 × 4 up to 16 × 16 pixels);
- Multi-picture motion compensation using previously encoded frames as a reference, thus allowing up to 32 reference frames (pictures);
- **FMO** (Flexible Macro Block Ordering);
- Specially coded slices (frames) **SP** and **SI** those enable efficient switching between video streams and efficient random access for video decoders;
- Integer transform (similar to the DCT transform in MPEG-2) for the reduction of rounding errors;

- Secondary Hadamard transform applied on DC coefficients of the primary spatial transform in order to obtain even more compression in smooth areas of the picture;
- Quarter-pixel precision for motion compensation (half-pixel in MPEG-2);
- **CAVLC** (Context Adaptive Variable Length Coding) instead of the statistic VLC coding in MPEG-2;
- **CABAC** (Context Adaptive Binary Arithmetic Coding) performing a lossless compression on account of probabilities of syntax elements in a given context;
- Weighted prediction providing a significant performance increase in special cases such as cross-fade transitions, fade-in, fade-to-black, etc.;
- Adaptive de-blocking filter decreasing the blocking artifacts, which degrade the picture quality in the edge especially (captions etc.).

All the described operations are not applied in all the profiles of the MPEG-4 AVC standard (e.g., frames I and P are compressed only in the Basic BP Profile; no weighted prediction, CABAC coding, etc. are used as depicted in Fig. 1).

3. Profiles and Levels of the MPEG-4 AVC Standard

The MPEG-4 AVC standard includes the following 6 (7) profiles, each supporting a particular set of coding functions (for various applications).

- **Baseline Profile BP** – is used for applications in PC, videoconferencing, mobile communications etc., and does not support the interlaced video.
- **Main Profile MP –** has been previously developed for the consumer electronics and TV broadcasting, includes a support for the interlaced video, and presently is completed by the profile HiP.
- **Extended Profile XP** – has relatively high compression efficiency and high robustness against the failures of the data stream. It does not support the interlaced video.
- **High Profile Hi P** – is the basic profile for TV broadcasting (HDTV especially) and superior optical video storage (e.g. HD DVD, Blu-Ray Disc etc.). It supports the sampling format **4:2:0** and 8-bit quantization of video signal samples.
- **High 10 Profile 10 Hi 10 P** is similar to the profile Hi P, but it supports up to 10 bits quantization of video signal samples.
- **High 4:2:2 Profile Hi 422 P** has been developed for professional applications; supports interlaced video, sampling format **4:2:2**, up to 10 bits quantization.
- **High 4:4:4 Profile Hi 444 P** is a deprecated profile supporting the interlaced video, the sampling format **4:4:4**, up to 12 bits quantization.

The MPEG-4 AVC standard includes 5 basic levels and the number of sub-levels**,** which present a performance limit of an encoder and decoder. These levels differ in the parameters such as the maximum number of macro-blocks per frame, the maximum coded bite-rate, the sample processing rate, and memory requirements especially. We can simply say, higher the level number is, higher the number of macro-blocks and pixels in the picture (higher resolution,) and higher the bit-rate (the encoder and the decoder have to process) is. For example, the **level 1** in the **profile BP** enables to encode the picture with resolution 176 × 144 pixels at 15 frames/s and maximum bit-rate 64 kbit/s, and the **level 5** in the profile **Hi 422P** enables to encode the picture with resolution 2560 × 1920 pixels at 30 frames/s and maximum bit-rate 540 Mbit/s (see Tab.1).

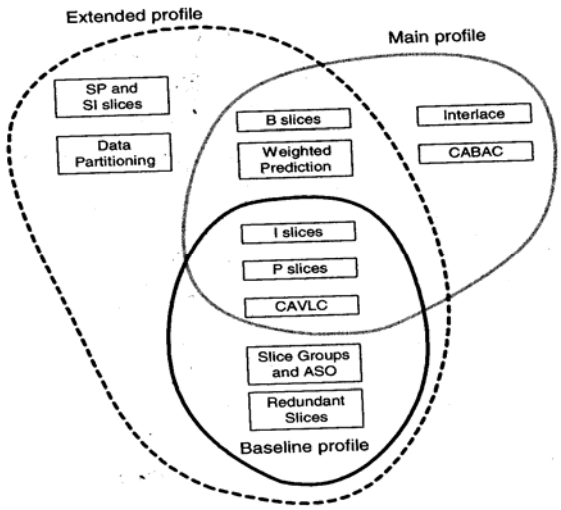

Fig.1. Schematics of a particular set of coding functions in 3 profiles of the MPEG-4 AVC standard; taken from [1].

4. Conclusions

The MPEG-4 AVC compression algorithm exhibits a significant increase of the compression efficiency compared to the currently used standard MPEG-2. The MPEG-4 AVC algorithm presents the past dispute about the future of the digital broadcasting in all the standards (DVB-S, DVB-T, DVB-C) for the television with the standard resolution (576 × 720 pixels) by means of the desirable increase of the number of programs in the contemporary multiplexes, but especially for the television with the high resolution HDTV (720 × 1080 pixels progressive or 1080 × 1920 pixels interlaced). This standard will be used in the system of the mobile TV reception (standards DVB-H – Handheld and DMB (Digital Multimedia Broadcasting) with the lower resolution (360 × 288 pixels) and with lower bit-rate.

Level number	Max. macro-blocks per second	Max. macro-blocks per frame	Max. bit-rate for profiles BP EP and XP	Max. bit-rate for profile HiP	Max. bit-rate for profile Hi10P	Max. bit-rate for profiles Hi 422P, Hi 444P
1.0	1485	99	64 kbit/s	80.0 kbit/s	192 kbit/s	256 kbit/s
1.1	3000	396	192 kbit/s	240.0 kbit/s	576 kbit/s	768 kbit/s
1.2	6000	396	384 kbit/s	480.0 kbit/s	1152 kbit/s	1536 kbit/s
1.3	11880	396	768 kbit/s	960.0 kbit/s	2304 kbit/s	3072 kbit/s
2.0	11880	396	2 Mbit/s	2.5 Mbit/s	6 Mbit/s	8 Mbit/s
2.1	19800	792	4 Mbit/s	5.0 Mbit/s	12 Mbit/s	16 Mbit/s
2.2	20250	1620	4 Mbit/s	5.0 Mbit/s	12 Mbit/s	16 Mbit/s
3.0	40500	1620	10 Mbit/s	12.5 Mbit/s	30 Mbit/s	40 Mbit/s
3.1	108000	3600	14 Mbit/s	17.5 Mbit/s	42 Mbit/s	56 Mbit/s
3.2	216000	5120	20 Mbit/s	25.0 Mbit/s	60 Mbit/s	80 Mbit/s
4.0	245760	8192	20 Mbit/s	25.0 Mbit/s	60 Mbit/s	80 Mbit/s
4.1	245760	8192	50 Mbit/s	62.5 Mbit/s	150 Mbit/s	200 Mbit/s
4.2	522240	8704	50 Mbit/s	62.5 Mbit/s	150 Mbit/s	200 Mbit/s
5.0	589824	22080	135 Mbit/s	169.0 Mbit/s	405 Mbit/s	540 Mbit/s
5.1	983040	36840	240 Mbit/s	300.0 Mbit/s	720 Mbit/s	960 Mbit/s

Tab.1. Basic parameters of the levels of the standard MPEG-4 AVC for various profiles.

Some providers broadcast presently by the satellites ASTRA (19.2° E and 23.5° E) **11 digital HDTV programs** (5 programs from those are broadcasted FTA – Free to Air).

These programs are broadcasted in the standard DVB-S and their HDTV source signals are compressed by the algorithm MPEG – 2 (e.g. Canal + HD-Promo, HD1, HD2/ HD5). The remaining 6 programs are broadcasted in the improved digital standard DVB-S2 and their HDTV signals are compressed by the described AVC algorithm (e.g., Anixe HD, Premiere HD Film, Premiere HD Sport, Prosieben HD, Sat.1 HD).

A corresponding digital satellite receiver (set top box) with a demodulator DVB-S (DVB-S2) and a decoder MPEG-4 AVC (MPEG-2) are necessary for the reception of these programs. A number of satellite broadcasted programs (channels) shall grow up with regard to the considerably higher frequency bandwidth of satellite transponders. The application of HDTV in terrestrial digital broadcasting DVB-T shall run evidently slower. This process shall be influenced by the interest of viewers and by the ability of producers of corresponding receivers, providers of HDTV programs and providers of DVB-T broadcasting.

Notice 2: A significant qualitative difference between the picture with the high resolution (HDTV) and the picture with the standard resolution (SDTV) can be observed on big pictures displayed by new-generation displays (LCD, plasma) with high resolution (so-called HD ready), format 16:9 and diagonal greater than 80 cm (in case of the relatively high priced TV receivers) only. Then the price of the set top box itself (DVB-T, DVB-S, DVB-S2) is insignificant compared to the price of the entire receiver.

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