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| Question: | 6/21 (VCEG)  |
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| Title: | **Entropy coding modifications for H.BWC** |
| Purpose: | Proposal |

**Abstract**

The current H.BWC development specifies two entropy coding methods: context-based adaptive binary arithmetic coding (CABAC) and adaptive variable-length coding (i.e., Huffman coding). Depending on the coding conditions—for example, whether prediction is applied to a given block—one of the two entropy coding methods is selected.

Each entropy coding path has been optimized for specific scenarios:

* The CABAC path is mainly optimized for blocks of quantization indices generated using prediction and was primarily designed for smaller block sizes.
* The variable-length coding (VLC) path is mainly optimized for large block sizes without prediction.

This contribution proposes a modification to the CABAC path for coding quantization indices of transform coefficients obtained by applying the DCT-II approximation, referred to as transform coefficient levels (short levels) in the remainder of this document. The proposed changes result in improved compression efficiency under a broader range of coding conditions, as demonstrated by the presented experimental results.

It is therefore proposed to further investigate the suggested modifications in a Core Experiment.

1. **Review of the level coding with CABAC in H.BWC**

The coding of a block consisting of transform coefficient levels using CABAC starts with signaling the last significant position when scanning the block forward, starting from the first element. A distinctive characteristic of this process is that if the last significant position is also the first position of the block, the significance flag—indicating whether the transform coefficient level is non-zero—is still coded. This allows for omitting a separate coded block flag.

After signaling the last significant position, the levels are signaled in reverse order, from the last significant position back to the first position in the block. For each absolute transform coefficient level, a binarization process is applied, decomposing the absolute level into a sequence of binary values (bins), which can be uniquely mapped back to the original absolute level.

Each bin coded in CABAC either employs an adaptive context model (regular coding mode) or none (bypass mode). Finally, if a transform coefficient level is non-zero, its sign is signaled in bypass mode.

## Binarization

The binarization of absolute transform coefficient levels consists of three stages. First, it is signaled whether the absolute level is greater than zero; this serves as the significance flag. If this is the case, additional flags indicate whether the absolute level is greater than one, greater than two, and so on, up to a predefined limit, which is set to 21 in the current H.BWC specification. This portion of the binarization is referred to as the truncated unary code. If the absolute level exceeds the final threshold of the truncated unary code, the remaining value is coded using 0th-order Exponential-Golomb code. The sign is signaled separately at the end, provided the transform coefficient level is non-zero.

## Context Modelling

Context modelling refers to the process of choosing an appropriate context model for the current bin to be coded. In H.BWC, context modelling for transform coefficient levels has two fundamental aspects: the position-dependent context model offsets, which depend on the current position within the block, and the template-dependent context model offset, which evaluates the sum of the three preceding coded absolute transform coefficient levels relative to the current position within the current block.

The position-dependent context model offsets use a fixed lookup table consisting of the values 0, 1, 2, 3, 7, 11, 15, and 23. This means that the DC position and the first three AC positions each use a separate set of context models, while positions 4–7, 8–11, 12–15, 16–23, and positions greater than 23 each use separate context model sets. In total, nine context model sets are possible. These position-dependent context model offsets are used for the context modelling of the significance flags and the bins belonging to the truncated unary code.

For the significance flag, an inner context model offset is added to the position-dependent context model offset. Since all context model sets are distinct, and the possible range for the inner offset is between 0 and 2, each context model set employed for coding the significance flags consists of three context models. The inner context modelling uses the template sum calculated as described above, clipped to a maximum value of two, resulting in three possible outcomes.

For the bins belonging to the truncated unary code, no inner context model offsets are employed, resulting in one context model per context model set.

## Modifications to Binarization and Context Modeling

This contribution proposes modifications to the coding of the last significant scanning position, the binarization, and the context modelling as follows.

The last significant scanning position can be coded as in the current H.BWC specification, i.e., by signaling the absolute offset relative to the first position of the block, or as a difference relative to the last significant scanning position of the previously coded block within the same channel. Without modifying the existing context modelling for the last significant scanning position, coding the difference introduces the signaling of the sign in bypass coding mode. The decision to employ delta coding for the last significant position depends on the block size and the prediction mode used for the current block.

For the binarization, an adaptive approach is proposed on top of the binarization used in H.BWC. When the template sum exceeds a defined threshold, a parity flag is signaled after coding the significance flag. This parity flag uses a dedicated context model, and as a result, the magnitude to be signaled is halved. The remainder in this binarization path is coded in the same way as in the existing binarization, but the maximum threshold for the truncated unary code is doubled. Furthermore, different context models are used for this second binarization path.

An additional modification concerns the derivation of the template-based context model offset. Instead of clipping the sum directly to two, one is added to the sum, and a right shift by one is then performed. The result of this operation is clipped to two, as before.

Finally, the position-dependent context model sets are adjusted depending on the current block size. Given the nine context model sets, all block sizes less than or equal to eight employ a dedicated context model set for each position. When the block size is greater than eight, quantization is applied to the last entries so that the total number of sets remains equal to nine. For example, the values for a block size of 1024 are 4, 8, 16, 32, 64, 128, 256, 512; and for a block size of 2048 are 8, 16, 32, 64, 128, 256, 512, 1024.

1. **Experimental results**

The first set of experimental results is based on the CTC configuration, meaning that coding performance is evaluated relative to H.BWC version 1.0, which serves as the anchor. The candidate for the BD-rate calculation is a modified version of H.BWC 1.0 in which the proposed modification to the level coding is implemented.

**ECG-data:**Bit-Rate change: ‑0.31 %, Encoder-Runtime: 100.77 %, Decoder-Runtime: 100.64 %

**EEG-data (CHB-MIT):**Bit-Rate change: ‑3.49 %, Encoder-Runtime: 103.62 %, Decoder-Runtime: 106.11 %

**EMG-data:**Bit-Rate change: -1.36 %, Encoder-Runtime: 103.54 %, Decoder-Runtime: 101.19 %

The presented experimental results show that the proposed modifications provide improved compression efficiency under the CTC configuration. Further experimental results demonstrating the performance of the proposed transform coefficient level coding in combination with LMS prediction and non-CTC configurations can be found in VCEC-BX14.

**References**

[1] VCEG, “Reference software for biomedical waveform data compression,” tag BWC-1.0. 🌍: <https://vcgit.hhi.fraunhofer.de/vceg-sw/bwc/-/tags>, presets *combined...cfg* in directory*bwc/cfg*

[2] J. Pfaff, C. Fersch, and Rapporteur Q6/21, “Common test conditions and evaluation procedures for H.BWC technical experiments,” *ITU-T document SG21-TD68/WP3*, Geneva, Jan. 2025. 🌍: <https://www.itu.int/wftp3/av-arch/video-site/2501_Gen/T25-SG21-TD-WP3-068-BWC-CTC.docx>

1. **Patent Rights Declaration**

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