Core Experiment on Selective Shaping for H.BWC

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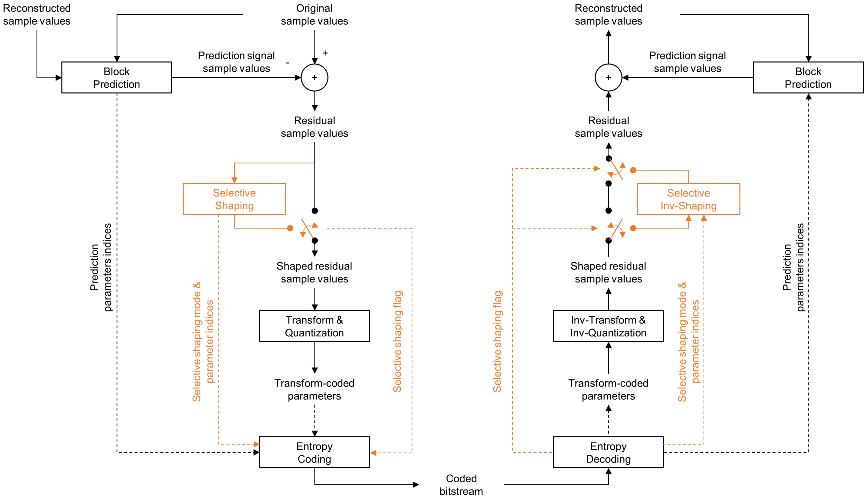
Motivation and Background

- **Predictive Coding of Waveforms**
  - Block-based predictive transform coding reduces redundancy.
  - Residual signals may still contain significant temporal/spectral dynamics.
- **Bottleneck in Coding Efficiency**
  - High-energy transient or spectral components degrade compression.
  - Aim to shape the residual to better control dynamic range.
- **Proposal: Selective Shaping**
  - Apply an additional adaptive modification before transform.
  - Goal: Achieve improved rate-distortion (RD) performance.

Overview of the CE System

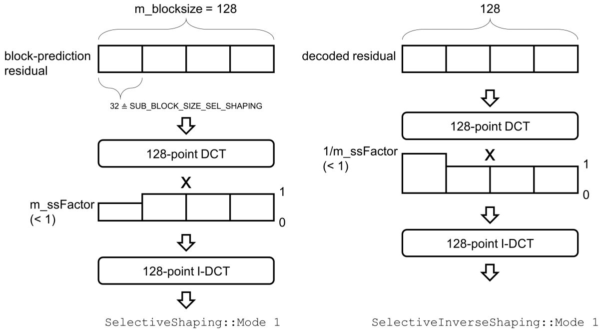


Selective Shaping Concept

- **Adaptive Modification of Residual:**
  - Inserted prior to transform & quantization.
  - Dynamically adjusts residual energy distribution.
- **Modes of Operation (per-block):**
  1. Mode 0: No shaping
  2. Mode 1: Selective sub-band spectral shaping
  3. Mode 2/3: Selective temporal shaping (left or right attenuation)
  4. Mode 4: Selective sub-block spectral shaping
- **Block-level Decision:** `estimateMode`
  - Evaluate RD performance for each mode.
  - Select best mode adaptively.

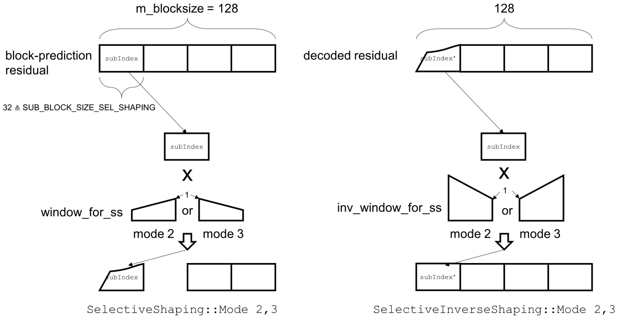
Mode 1: Selective sub-band spectral shaping

- Especially effective when low-frequency energy dominates.
- Uniform dynamic range reduction across the entire block.
- **Overhead:** Additional transform steps, but negligible decode overhead.

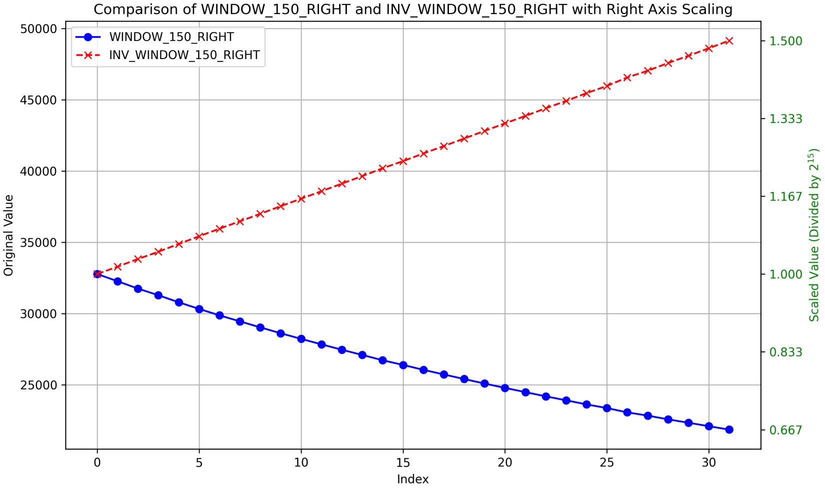


Modes 2 and 3: Selective temporal shaping

- Divide block into fixed-size sub-blocks.
- Select target sub-block (based on the maximum energy) via `SubblockIndex`.
- Window coefficients typically fixed depending the data type and input step size.
- Performed in time domain with fixed-point arithmetic.

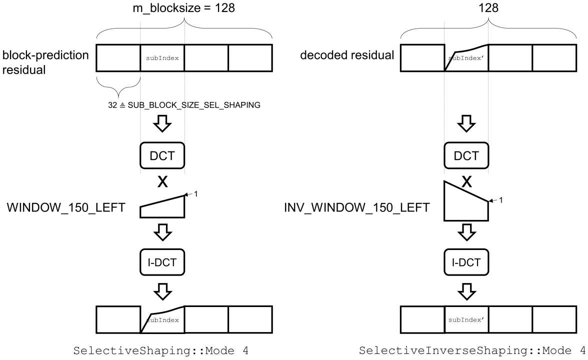


Right-Attenuated Window and its Inverse



Mode 4: Selective sub-block spectral shaping

- Selectively reducing low sub-band for the selected sub-block.
- Slightly higher than full-block approach but localized effect.



Adaptive Parameter Selection

- Function `setWindowDepthForSS()`
- Examines StepSizeForQP and signal type (ECG, EMG, EEG).
- Selects attenuating value and scaling factor (`m_ssFactor`).
- Fine-grained control over shaping intensities.
- Reduced overhead from per-channel adaptivity.

Dataset	Condition	m_ssFactor	Attenuating value
ECG	StepSizeForQP < 5	1.1	1.2
	StepSizeForQP < 9	1.2	1.5
	StepSizeForQP >= 9	1.4	1.8
EMG	StepSizeForQP < 5.5	1.1	1.1
	StepSizeForQP < 25.5	1.2	1.4
	StepSizeForQP >= 25.5	1.4	1.6
EEG	StepSizeForQP < 4	1.2	1.1
	StepSizeForQP < 11	1.3	1.3
	StepSizeForQP < 33	1.4	1.5
	StepSizeForQP >= 33	1.5	1.7

Syntax Elements

- **selective_shaping_flag**: 3-bit field
  - 0: No shaping
  - 1: Mode 1
  - 2: Mode 2
  - 3: Mode 3
  - 4: Mode 4
- **selective_subblock_index**:
  - Signaled if `selective_shaping_flag > 1`
  - Identifies sub-block region to be shaped
- **Context Modeling**:
  - 5 contexts for SS flag based on `prevSSFlag`
  - 4 contexts for sub-block index from `prevSubBlock`

Syntax Modifications: New Elements

frame_data(numChannels) {	**Descriptor**
...	
block_abs_delta_qp	ae(v)
selective_shaping_flag // New syntax for selective shaping	ae(v)
// A 3-bit field indicating the selective shaping mode:	
// 0: No selective shaping is applied.	
// 1: Mode 1, 2: Mode 2, 3: Mode 3, 4: Mode 4	
if (selective_shaping_flag > 0) {	
if (selective_shaping_flag > 1) {	
selective_subblock_index	ae(v)
}	
}	
}	

Exponential-Averaged Context Update

- **prevSubBlock** updated with a weighted average:
  - If channel=0, set directly to current sub-block index.
  - Otherwise,

$$\text{prevSubBlock} = \alpha \cdot \text{currIndex} + (1 - \alpha)\text{prevSubBlock}$$

  where

$$\alpha = \text{PREV\_SUB\_MUL\_FACTOR}/\text{PREV\_SUB\_DIV\_FACTOR}$$

- **Benefit:**
  - Smooth context transition for CABAC.

Test Configurations

- **Datasets:** MIT ECG , Ozdemir EMG, CHBMIT, NMR55, NMR57 EEGs
- **Configurations:**
  - ECG: combinedPresetECG.cfg, combinedPresetECG_IndepChannel.cfg
  - EEG: combinedPresetEEG.cfg, combinedPresetEEG_IndepChannel.cfg
  - EMG: combinedPresetEMG.cfg, combinedPresetEMG_IndepChannel.cfg
- **Target StepSizeForQPs**
  - ECG: [1.125, 1.5, 2, 3, 4, 5.5, 7, 9, 11, 13.5, 16, 19, 22], excluded 1
  - EEG: [1.5, 2, 3, 4, 5.5, 7, 9, 11, 13.5, 16, 22, 33, 44, 55, 66, 77, 88, 99, 110], excluded 1, 1.125
  - EMG: [1.5, 2, 3, 4, 5.5, 7, 9, 11, 13.5, 16, 19, 22, 25.5, 29, 33, 37, 41.5, 46, 51, 56, 60.5], excluded 1
- **Metrics:**
  - BD-rate1, BD-rate2, EncT, DecT overhead
- **Anchor:** H.BWC TM (tag ver.)

Results

- Negative BD-rate values across signals → efficiency gain

Config	Dataset	BD-rate #1 (%)	BD-rate #2 (%)	Δ EncT (%)	Δ DecT (%)
Joint	MIT_ECG	-0.379	-0.380	37.55	9.72
	Ozdemir_EMG	-0.241	-0.241	98.18	8.59
	CHBMIT_EEG	-0.172	-0.167	90.31	0.51
	NMR55_EEG	-0.266	-0.311	88.27	4.11
	NMR57_EEG	-0.175	-0.172	56.65	-3.78
Independent	MIT_ECG	-0.348	-0.350	40.44	9.42
	Ozdemir_EMG	-0.168	-0.171	60.89	8.69
	CHBMIT_EEG	-0.189	-0.193	61.50	11.98
	NMR55_EEG	-0.152	-0.164	55.25	6.00
	NMR57_EEG	-0.205	-0.200	51.09	13.61

Conclusion

- By introducing an adaptive modification to the residual signal, the proposed method effectively controls the dynamic range of the residual signal prior to the transform.
- The results under two cfgs. across all datasets, consistently show negative BD-rate values.
- While the approach incurs a moderate encoder runtime overhead, the decoder complexity remains minimally affected.
- Future investigations may focus on optimizing the shaping parameters and extending the evaluation to additional signal types and test conditions.

- We sincerely request that the proposed technology be adopted in the next H.BWC Test Model.

Annex: Residual signal analysis: ECG

- The energy of the residual signals are logged and analyzed.
- K-means clustering with 4 clusters were performed to the normalized 8-dim energies.
- There are typical tendencies of nearly linear attenuation to the left and right.