MEDIATEK

JVET-K0236
CE2.5.2: Non-local mean filter (NLM)

Authors: Chen-Yen Lai, Ching-Yeh Chen, Yu-Wen Huang, Shaw-Min Lei

Presenter: Ching-Yeh Chen

Overall Summary

- NLM is utilized as one in-loop filter after deblocking filter (DF) and before sample adaptive offset (SAO) to reduce decoded sample distortions.
- There are two stages in NLM, including block matching and denoising process
- Experimental results

		VTM-1.0					BMS-1.0				
		Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
NLM	AI	-0.63%	-1.98%	-1.99%	102%	235%	-0.31%	-1.45%	-1.48%	100%	167%
	RA	-1.24%	-3.95%	-3.49%	100%	211%	-0.57%	-3.57%	-3.25%	100%	139%
	LB	-1.00%	-3.99%	-4.24%	101%	179%	-0.76%	-3.94%	-3.99%	101%	138%

Basic Flow of NLM

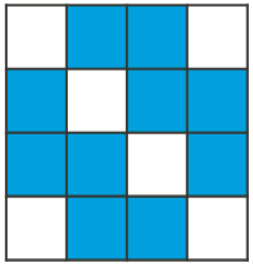
- Divide one image into **8x8** non-overlapped patches
- Based on on/off control flags, apply NLM to those to-be-processed patches
- Two stages for NLM:
  - Block matching stage: perform ME with **multi-subsample pattern based search (MSPS)** and **neighbor-based fast search algorithm (NBFS)** to form one patch group for each to-be-processed patch
  - Denoising stage: apply **NLM technology** to modify samples in one patch group

Multi-Level On/Off Control Flags

- Three modes in slice level
  - SliceAllOn, SliceAllOff, and CTBCtrl
- If CTBCtrl is used for current slice, three modes can be used for each CTB
  - CTBAlloff, CTBAllon, and BlkOnOff
- If BlkOnOff is used for current CTB, then signal one on/off control flag for each control unit with size equal to 32x32

Block Matching Stage

- Two MV search methods are multi-subsample pattern search (MSPS) and neighbor-based fast search (NBFS)

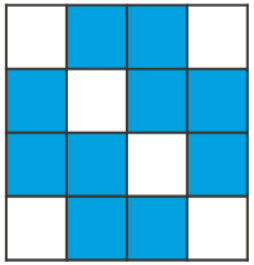


In an on-off control unit, apply MSPS to white patches and apply NBFS to blue patches

- Multi-subsample pattern search:
  - Perform ME in the searching range, [-16, 16]
  - Apply two-stages searching algorithm with different sub-sample steps to find 15 nearest patches
  - A refinement is applied to those 15 nearest patches one by one to derive the final 15 reference patches

Block Matching Stage

- Neighbor-based fast search:
  - Predictor-based search algorithm
  - The searching results of all MSPS patches in an on-off control unit can be used to be initial candidates
  - Find 15 nearest patches among these initial candidates
  - And then a refinement is applied to those 15 nearest patches one by one to derive the final 15 reference patches



In an on-off control unit, apply MSPS to white patches and apply NBFS to blue patches

Denoising Stage

- Decide the corresponding weight for each reference patch based on the distortion between current patch and reference patch
- Modify samples in current patch by accumulating the weighted sum of sample value in the reference patch and the corresponding weight
- Modify samples in reference patch by using the weighted sum of sample value in current patch and the corresponding weight
- Apply normalization to derive the filtered sample value

Simulation Results

	All Intra Main10									
	Over VTM-1.0					Over BMS-1.0				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-0.60%	-2.19%	-2.01%	102%	213%	-0.26%	-1.61%	-1.36%	100%	161%
Class A2	-0.45%	-1.40%	-1.00%	103%	257%	-0.20%	-0.80%	-0.73%	100%	171%
Class B	-0.48%	-1.87%	-2.11%	102%	237%	-0.23%	-1.13%	-1.39%	100%	160%
Class C	-0.47%	-1.63%	-1.87%	101%	179%	-0.27%	-1.70%	-1.99%	100%	147%
Class E	-1.27%	-3.02%	-2.90%	103%	337%	-0.69%	-2.15%	-1.84%	100%	212%
Overall	-0.63%	-1.98%	-1.99%	102%	235%	-0.31%	-1.45%	-1.48%	100%	167%
Class D	-0.12%	-0.92%	-0.88%	102%	158%	-0.03%	-0.58%	-0.55%	100%	129%
Class F (optional)	-0.49%	-1.40%	-1.42%	103%	249%	-0.36%	-1.66%	-1.73%	100%	192%

	Random Access Main 10									
	Over VTM-1.0					Over BMS-1.0				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1	-1.70%	-6.56%	-5.67%	100%	337%	-0.63%	-4.52%	-3.89%	100%	168%
Class A2	-1.52%	-3.82%	-2.25%	100%	195%	-0.79%	-3.76%	-2.43%	100%	128%
Class B	-1.36%	-3.77%	-3.67%	101%	208%	-0.65%	-3.79%	-3.81%	100%	141%
Class C	-0.52%	-2.32%	-2.57%	100%	160%	-0.24%	-2.42%	-2.68%	101%	125%
Class E										
Overall	-1.24%	-3.95%	-3.49%	100%	211%	-0.57%	-3.57%	-3.25%	100%	139%
Class D	-0.17%	-0.93%	-1.17%	101%	136%	0.02%	-1.04%	-1.00%	101%	113%
Class F (optional)	-0.56%	-1.71%	-1.76%	101%	211%	-0.38%	-1.85%	-1.77%	101%	156%

	Low delay B Main10									
	Over VTM-1.0					Over BMS-1.0				
	Y	U	V	EncT	DecT	Y	U	V	EncT	DecT
Class A1										
Class A2										
Class B	-1.16%	-4.59%	-5.11%	101%	217%	-0.71%	-4.67%	-4.96%	101%	154%
Class C	-0.63%	-2.60%	-2.62%	101%	176%	-0.52%	-2.25%	-2.74%	101%	141%
Class E	-1.23%	-4.83%	-4.94%	101%	131%	-1.15%	-4.98%	-4.04%	101%	113%
Overall	-1.00%	-3.99%	-4.24%	101%	179%	-0.76%	-3.94%	-3.99%	101%	138%
Class D	-0.31%	-1.89%	-1.53%	101%	141%	-0.14%	-1.35%	-1.54%	101%	120%
Class F (optional)	-0.92%	-1.30%	-0.75%	102%	219%	-0.74%	-0.62%	-0.28%	101%	168%

Conclusions

- Proposed NLM in-loop filter to reduce decoded sample distortions
- Experimental results
  - NLM achieves -0.63%, -1.24%, and -1.00% luma BD-rates for AI, RA, and LB, respectively, with 135%, 111%, and 79% decoding time increases on VTM-1.0
  - NLM achieves -0.31%, -0.57%, and -0.76% luma BD-rates for AI, RA, and LB, respectively, with 67%, 39%, and 38% decoding time increases on BMS-1.0.
- Thank Kwai for cross-checking

Thank You

Denoising Stage

- All samples in one patch group can be modified.
- The SampleValue and SampleWeight of each sample in the current patch are generated by the following equations.

$$SampleValue[m,n] = \sum_{i=0}^{15} weight_i[m,n] * RecSample_i[m,n]$$

$$SampleWeight[m,n] = \sum_{i=0}^{15} weight_i[m,n]$$

  - $[m,n]$ is the position of a to-be-processed sample in a patch, $RecSample_i[m,n]$ is the sample value at position $[m,n]$ in the i^{th} patch before NLM (i=0 means current patch, i>0 means a reference patch), $weight_i[m,n]$ is the corresponding weight of to-be-processed samples.

Denoising Stage

- As for each sample in the 15 best reference patches, the SampleValue and SampleWeight are generated by the following equations,

$$SampleValue[m,n] = weight_i[m,n] * RecSample_0[m,n]$$

$$SampleWeight[m,n] = weight_i[m,n]$$

  - The weight, $weight_i[m,n]$, is derived based on the estimated quantization noise and SSD between the current patch and the i^{th} reference patch.