LOW COMPLEXITY JOINT RDO OF PREDICTION UNITS COUPLES FOR HEVC INTRA CODING

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I. Context & Contribution

- MPEG Intra Coding generates dependencies between Coding Units (*CU*): Closed-Loop prediction and *CABAC*
- Dual Joint Rate-Distortion Optimization (*Dual-JRDO*) is an exhaustive search for prediction parameters which minimizes a cost function affecting two neighbor *CUs*
- Contribution : A low complexity version is proposed in order to estimate opportunities for real-time encoding

II. Dual-JRDO Model

- **Notations**
  - Coding parameters: $\vec{p}$
  - Index of *CU*: i
  - Distortion D and Rate R
  - R-D Cost Function: $J(\vec{p})$

Example of CTU partitioned into 16 CUs optimized through Dual-JRDO

0	1	4	5
2	3	6	7
8	9	12	13
10	11	14	15

- ***Dual-JRDO* equation**
  - Exhaustive optimization of CUs 2 by 2 (dotted areas)
  - Parameter to optimize $\vec{p}$ is the prediction mode

$$\{p_i^*, p_{i+1}^*\} = arg \min_{\{p_i, p_{i+1}\}} (J_i(p_i) + J_{i+1}(p_i, p_{i+1}))$$

III. Acceleration Methods

1. Adapting to Spatial Activity

- **Down-sample 16x16 CUs into 4x4 CUs**
  - Pixel real position: m, n
  - Pixel down-sampled position: p, q
  - Pixel's luminance: I

$$I(p,q) = \frac{1}{16}\sum_{m=1}^{4}\sum_{n=1}^{4} I(p/4+m, q/4+n)$$

- **Compute the spatial activity**
  - Activity of *CU* i: g_i

$$g_i = \frac{1}{16}\sum_{p=1}^{4}\sum_{q=1}^{4} min\begin{cases}|I_i(p,q) - I_i(p-1,q)|\\|I_i(p,q) - I_i(p,q-1)|\end{cases}$$

- **If g_i lower than a threshold Th**
  - Do not apply *Dual-JRDO*
- **Th is dependent of quantizer QP**

$$Th(QP) = \alpha + e^{\beta * QP}$$

2. Short-listing of the depending *CU*

- **Observations**
  - *Dual-JRDO* sequentially optimized two prediction modes $\{p_i, p_{i+1}\}$
  - During p_{i+1} optimization, p_i is fixed
  - The second mode analysis is an independent optimization
- **Any fast solution which reduce the number of modes can be applied**
  - We choose one of the most efficient: Rough Mode Decision (*RMD*)
- ***RMD***
  - Estimate the Most Probable Modes (*MPMs*)
  - Estimate the modes with lowest *SATD* score
  - Create a shortlist based on this two sets
  - Apply *RDO* only on this shortlist

3. Residual Analysis based Clustering

- **Focusing on Distortion dependency**
  - Identical residue leads to identical reconstructed *CU*
  - If two modes results into the same decoded *CU*, the next *CUs* are impacted the same manner

Solution based on modes clustering

I. **During *RMD* process for p_i**
  - Cluster all modes based on their residue

II. **If p_i is the first analyzed mode of its cluster**
  - Consider all possible modes for p_{i+1}

III. **Otherwise**
  - Consider p_{i+1}^* attached to this cluster
  - Consider the new *MPMs* if its applies

IV. Performances

- **Test environment**
  - HM16.12 Anchor
    - RDO configuration
    - Common Test Conditions: All-Intra
  - PSNR based Bjontegaard computation
    - 5 QPs {22,27,32,37,42}

Average BD-BR	C_0	C_1	C_2	C_3	C_4
Class B	-0.45%	-0.42%	-0.38%	-0.46%	-0.35%
Class C	-0.61%	-0.54%	-0.47%	-0.61%	-0.42%
Class D	-0.63%	-0.59%	-0.46%	-0.64%	-0.44%
Class E	-0.64%	-0.58%	-0.52%	-0.64%	-0.47%
Class F	-0.87%	-0.76%	-0.67%	-0.88%	-0.60%
All	**-0.63%**	**-0.57%**	**-0.49%**	**-0.63%**	**-0.45%**
Best Sequence	**-1.12%**	**-1.01%**	**-0.87%**	**-1.11%**	**-0.82%**
Worst Sequence	-0.19%	-0.21%	-0.20%	-0.20%	-0.20%

- **Configurations of *Dual-JRDO***

C_0: No acceleration
C_1: Adapting to spatial activity
C_2: Short-listing of p_{i+1}
C_3: Residue clustering of p_i
C_4: All accelerations combined

Complexity (%)	C_0	C_1	C_2	C_3	C_4
Class B	1137%	411%	199%	699%	133%
Class C	1025%	540%	192%	702%	156%
Class D	945%	565%	197%	703%	160%
Class E	1091%	336%	199%	592%	116%
Class F	1099%	401%	193%	607%	124%
All	**1062%**	**454%**	**196%**	**666%**	**138%**
Best Sequence	**920%**	**198%**	**185%**	**467%**	**74%**
Worst Sequence	1266%	662%	212%	735%	178%

V. Conclusion

- **Observations**
  - *Dual-JRDO* is most effective on textured areas
  - Methods reducing the number of modes to test (as *RMD*) are efficient when extended to dependent CUs
  - Many predictions lead to same residual data and create redundant computations in dependent schemes
- **Conclusion**
  - *Dual-JRDO* can be highly speed up and be 5x faster
  - Even faster implementation can bring constant BD-BR improvement (-0.45%)
- **Future Work**
  - Use *Dual-JRDO* to improve other coding parameters: Quantization, Transform, Filters, …