I. Context & Objective

- Recent MPEG Intra Coding tools
  - Prediction use reconstructed samples
  - Context Adaptive Binary Arithmetic Coding (CABAC)
  - By design, these causal processes introduce Inter-Blocks Dependencies (see B.)

II. Inter-Block Dependencies

1. Intra Prediction in MPEG standards
   - Spatial projection of neighboring blocks (+DC/Planar)
   - Reference pixels are reconstructed
   - Distortion of one block may affect prediction of next ones

2. CABAC and Syntax Elements (SE)
   - SE are binarized into symbols of n bins
   - A context modeling provides estimates of conditional probabilities of each symbol bins
   - bin coding is dependent of probability model updates from previous coded bins
   - Syntax bits depends on previously coded syntax elements

III. Proposed Joint RDO Models

- Rate-Distortion Optimization (RDO)
  - Coding parameters \( \vec{p} \)
  - Distortion \( D \) and Rate \( R \)
  - Minimize R-D cost function:
    \[
    \min_{\vec{p}} D(\vec{p}), s.t. \; R(\vec{p}) \leq R_T
    \]
  - Turned into Lagrangian cost:
    \[
    \min_{\vec{p}} (D(\vec{p}) + \lambda \cdot R(\vec{p}))
    \]

- Proposed model: Joint RDO
  - For each block \( i \), within the frame \( F \)
  - Consider Inter-Block Dependencies:
    - Each block \( i \) is dependent from close ones
    \[
    \min_{\vec{p}} f(\vec{p}) = \sum_{i \in F} \min_{p_i} (J_i(p_i) + J_{i+1}(p_{i+1}))
    \]

IV. Performance

- Dual-JRDO
  - Optimize blocks 2 by 2 (dotted areas)
  - High dependencies due to spatial proximity and coding orders
    \[
    (p_i, p_{i+1}) = \arg\min_{p_i, p_{i+1}} (J_i(p_i) + J_{i+1}(p_{i+1}))
    \]

- Quad-JRDO
  - Optimize blocks 4 by 4
  - Better consideration of distortion propagation among all prediction modes (e.g. Vertical)
    \[
    (p_{i+1})_{k=r} = \arg\min_{p_{i+1}} \sum_{k=r}^{t=+3} J_i(p_{i+1})
    \]

- Test Configuration
  - Anchors in RDO:
    - HEVC (HM16.6)
    - H.264/AVC (JM19.0)
  - Configuration is All-Intra
  - First frame of each sequence
  - In HM, Quad-JRDO only apply to 4x4 blocks

- Observations
  - The more blocks are optimized concurrently, the more BD-BR reduction is achieved
  - Achievable gains of dependencies consideration are exhibited
  - Jointly optimizing prediction modes brings systematic and substantial bitrate savings

- Future Work
  - Different coding parameters can be optimized: QP, partitioning, lambda, ...
  - Extension to this work to temporal dependencies is envisaged

Average BD-BR gains

- JM19.0
- HM16.6

- Dual-JRDO
- Quad-JRDO

- Class B: -0.80% -1.84% -0.49% -0.79%
- Class C: -0.89% -1.89% -0.90% -1.90%
- Class D: -0.50% -1.51% -0.93% -1.98%
- Class E: -0.89% -1.89% -0.52% -1.33%
- All: -0.77% -1.78% -0.71% -1.47%

Best Sequence -1.37% -3.10% -1.31% -2.31%
Worst Sequence 0.08% -1.09% -0.21% -0.04%