Fast Partitioning for VVC Intra-Picture Encoding With a CNN Minimizing the Rate-Distortion-Time Cost

Gerhard Tech, Jonathan Pfaff, Heiko Schwarz, Philipp Helle,
Adam Wieckowski, Detlev Marpe, and Thomas Wiegand

Motivation

- Versatile Video Coding (VVC)
  - New coding tools e.g. for intra-picture coding:

    multi-type tree (MTT), intra sub-block partitions (ISP), matrix-based intra prediction (MIP), extended number of directional modes, multi-reference line (MRL), low-frequency non-separable transform (LFNST), multiple transform select (MTS) ...

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  ➔ Some modes must be skipped without testing
- Which modes should the encoder skip?
  - Optimally: Reduce encoding time, while not increasing the RD cost

  ➔ Subject of this presentation: Doing this by skipping MTT partitioning modes

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- How can the the partitioning be restricted?
  - VVC partitioning
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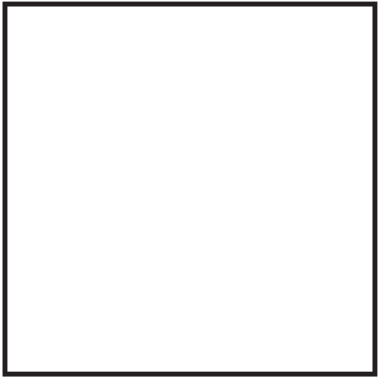
- Summary and Conclusion

VVC Partitioning

Partitioning Restrictions

- Combined quad and a multi-type tree



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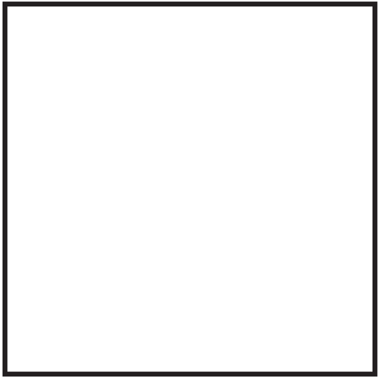

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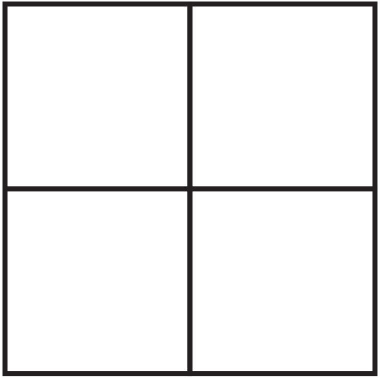

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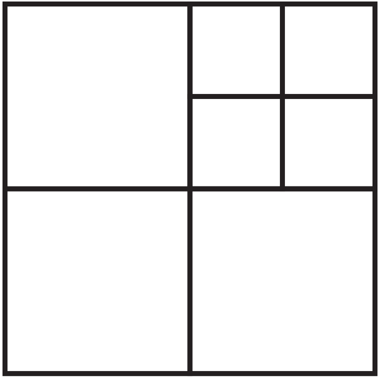

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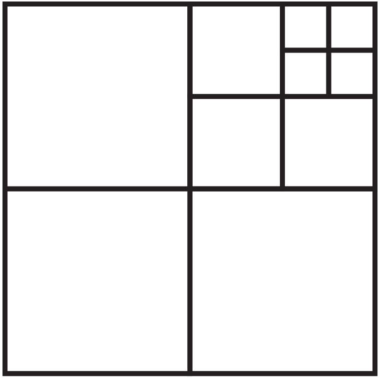

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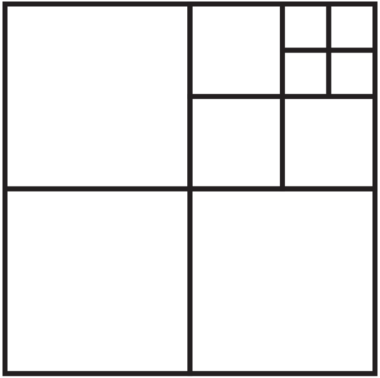

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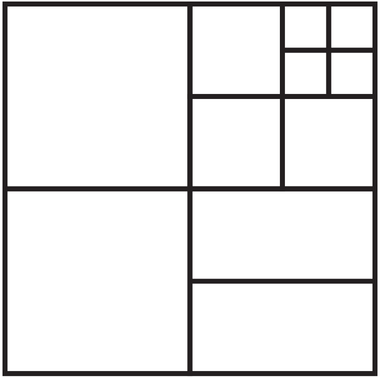

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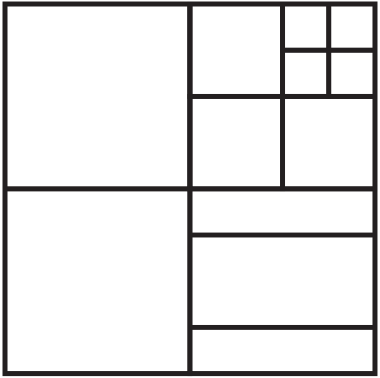

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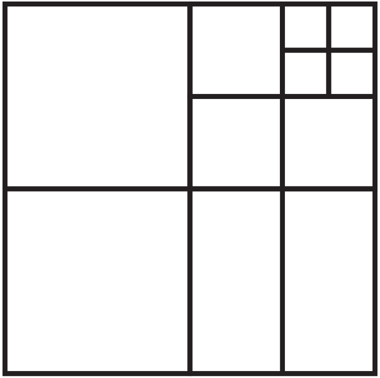

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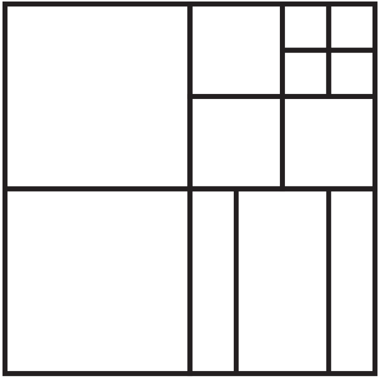

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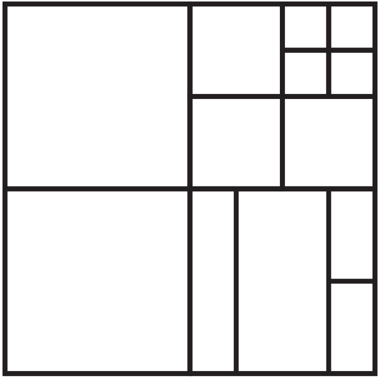

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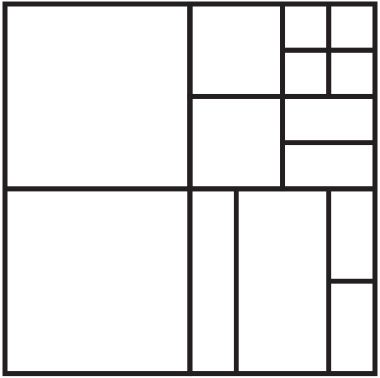

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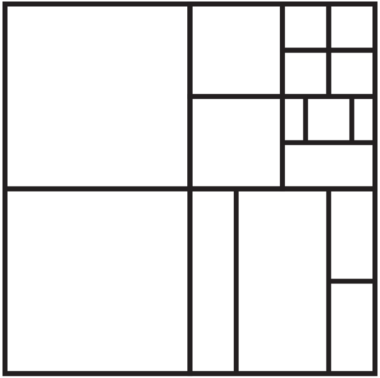

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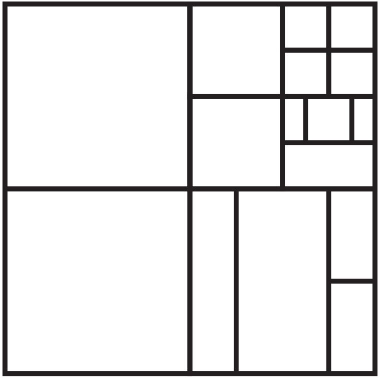

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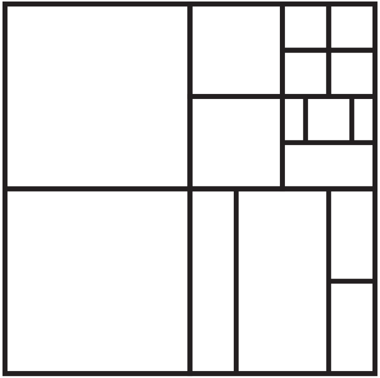

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→ Idea:
  - Skip partitioning modes based on the block content without testing
  - Introduce parameters controlling which modes are skipped

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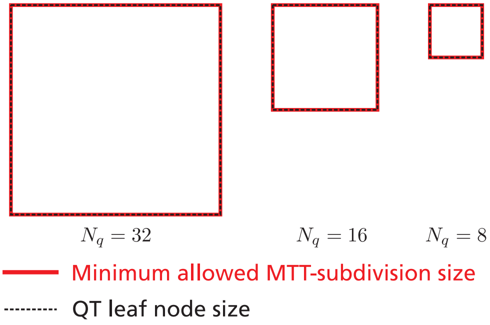

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Fraunhofer HHI

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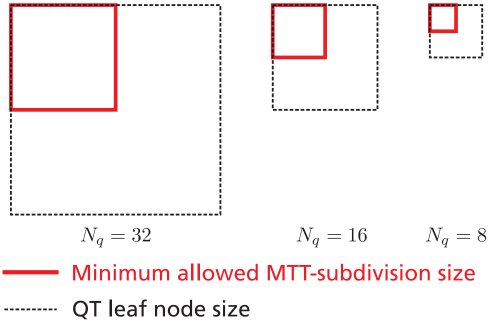

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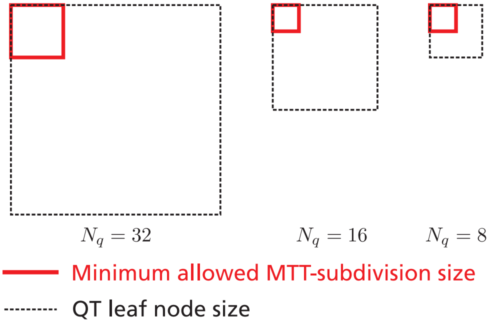

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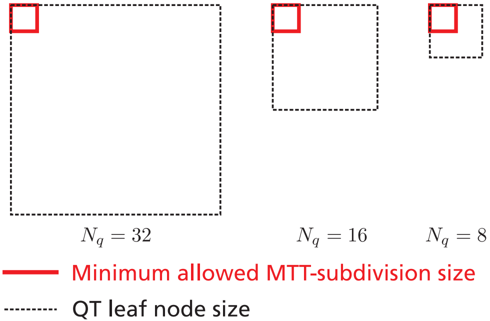

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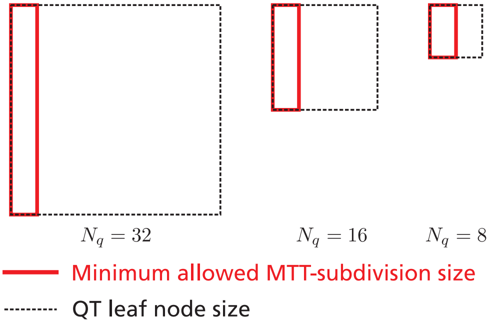

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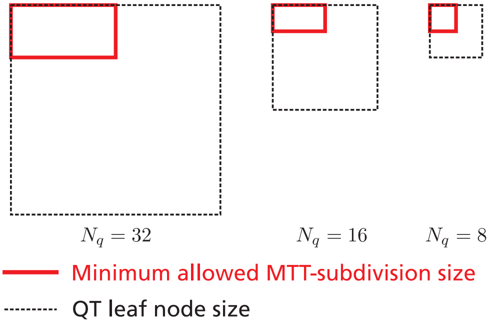

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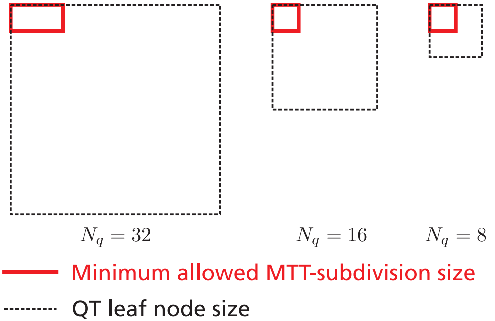

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→ Adaptation to block content possible

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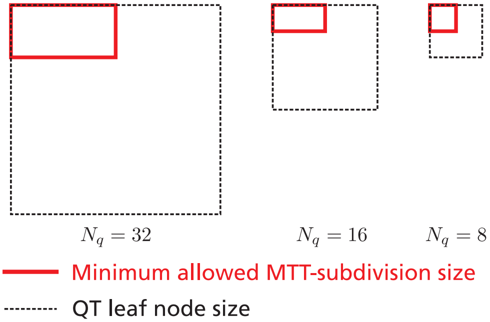

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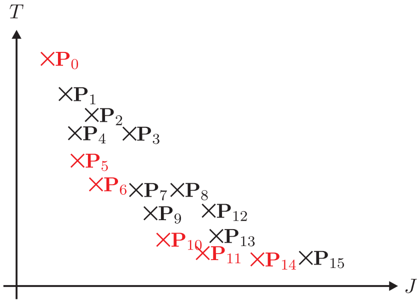

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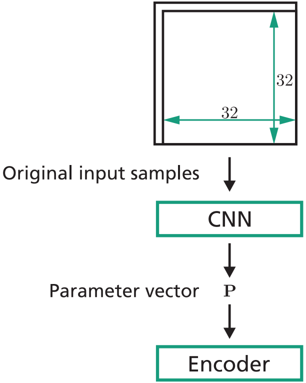

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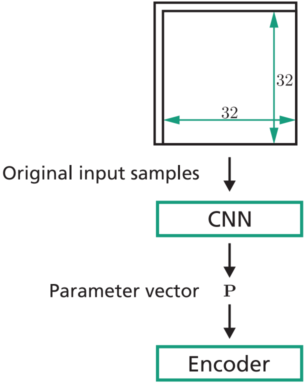
- Training Approach
  - Training data generation:
    - Perform the Lagrangian method
    - Record the occurring RDT-cost
  - In training:
    - Use the stored RDT cost to compute the training loss



Generation of Training Data

- Encode training sequences, for each 32×32 block B:
  - Encode B with all $\mathbf{P}$
  - Store the occurring RDT cost $K(\mathbf{P})$
  - Select $\mathbf{P}$ providing the minimum $K(\mathbf{P})$ and continue based on its encoder state

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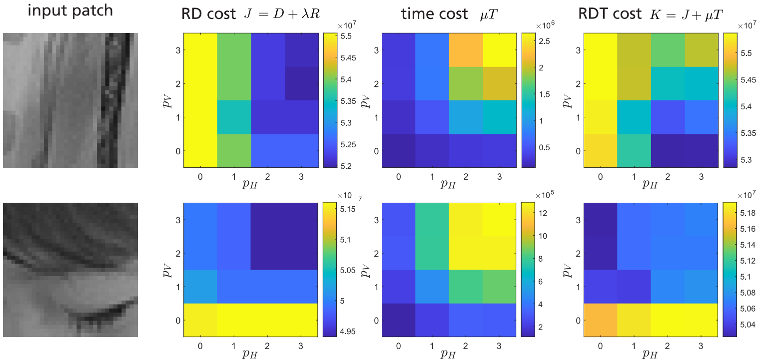

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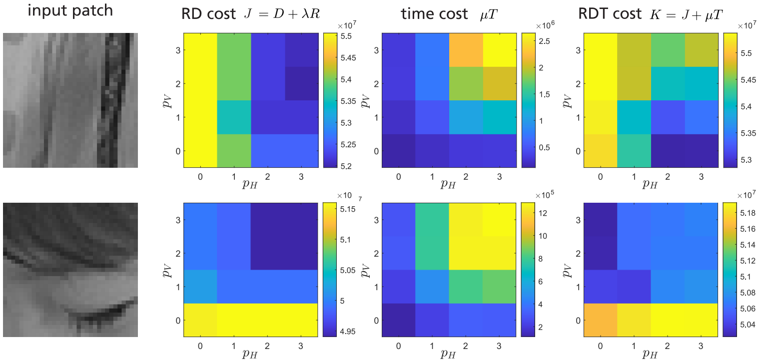

- Lagrange parameters:
  - λ: encoder default for QP
  - μ: determines encoding time

Loss Function in Training

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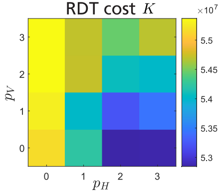
- Approach
  - Interpret the two floating point CNN outputs as p_H and p_V
  - Gradient descent method
  - Requires derivatives of loss function with respect to p_H and p_V
  - → Problem: K sampled at integer values; derivatives do not exist



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Loss Function in Training

- Objective: Minimize the RDT cost of estimated parameters
- Approach
  - Interpret the two floating point CNN outputs as p_H and p_V
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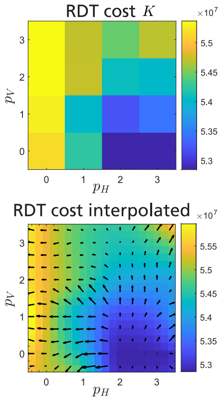

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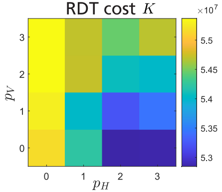

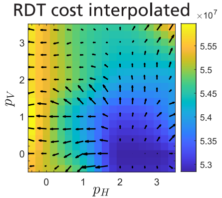

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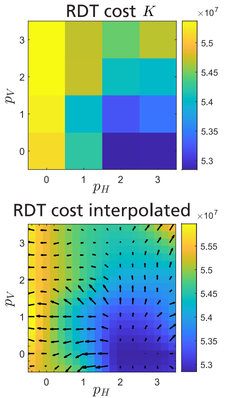
  - Ensures that the gradient descent method converges back



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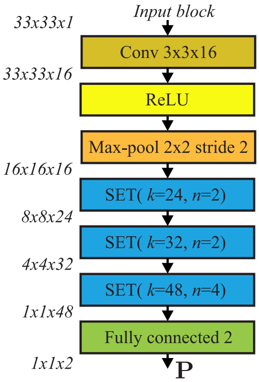
The CNN



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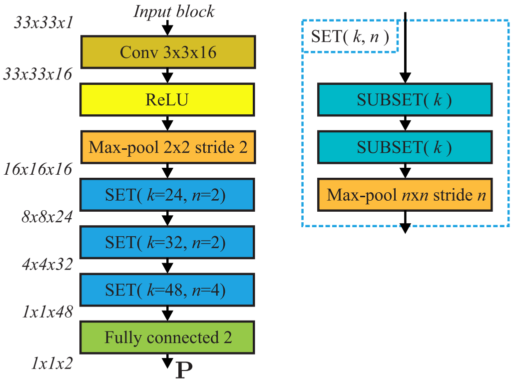

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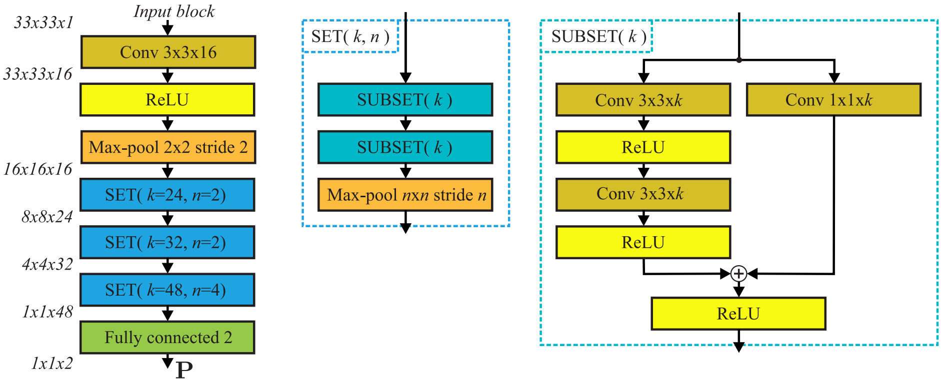

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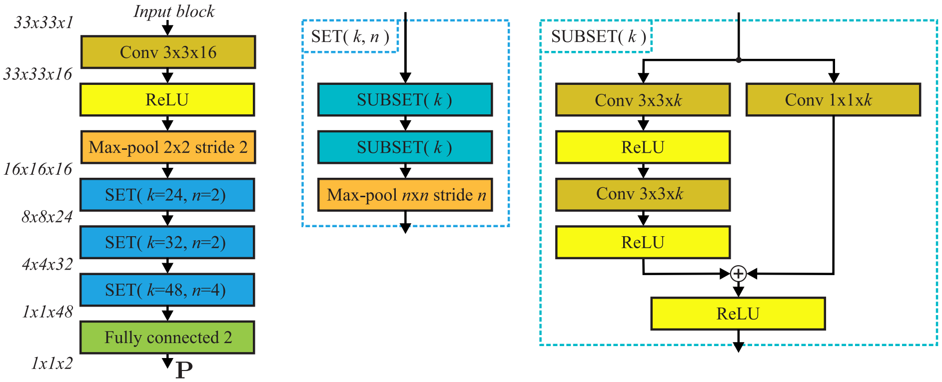

- Corresponds to CNN of Galpin (2019) and Tissier (2020) [inspired by ResNet]
- Modifications:
  - Max pooling size changed to input 33×33 instead of 65×65 blocks
  - 2 outputs instead of 480

Conditions

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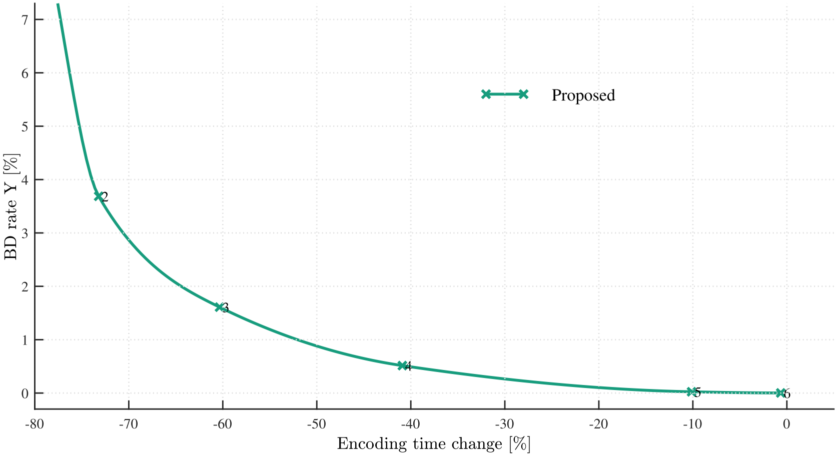
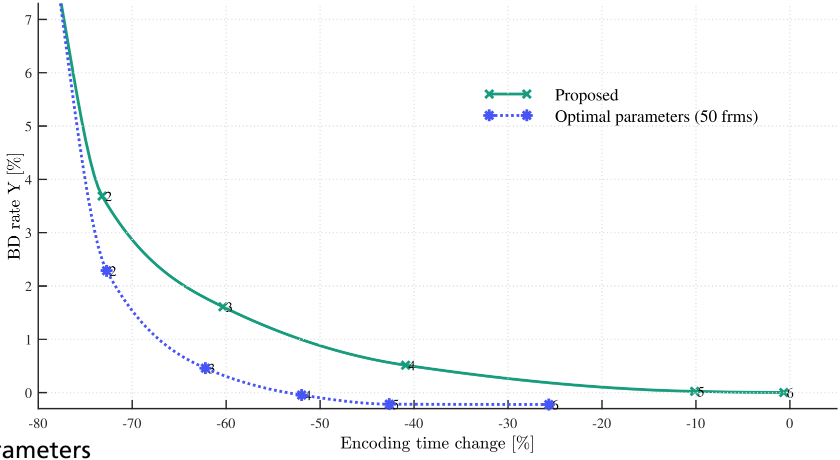
- Coding conditions
  - JVET's test conditions for All-Intra Coding
  - CNN run-times included
  - Basis and anchor: VTM-7.0
  - No default optimizations disabled

Results



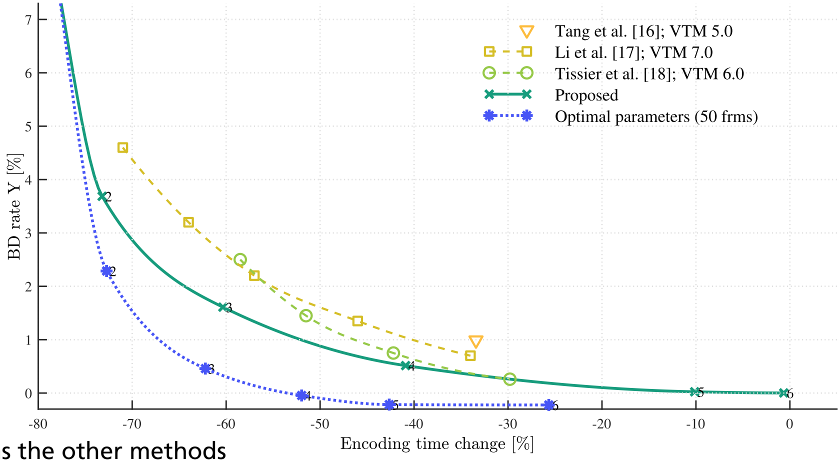
- Results
  - 10% encoding time reduction, neglectable BD rate increase
  - 50% encoding time reductions, 0.9% BD rate increase
  - 73% encoding time reductions, 3.7% BD rate increase

Results



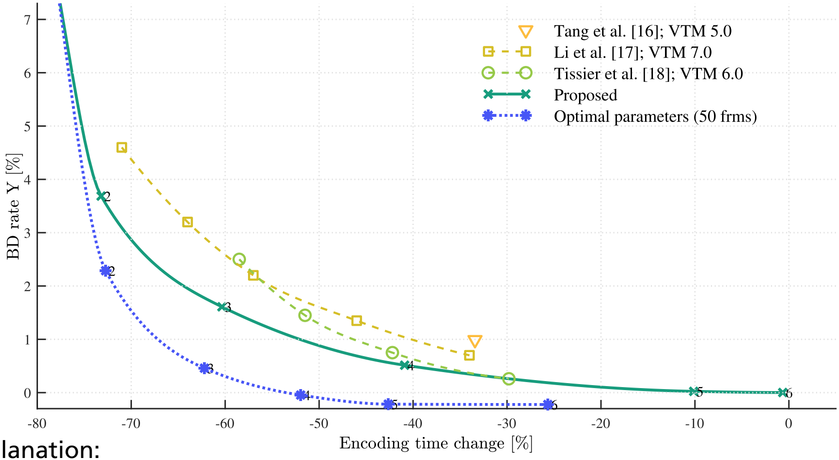
- Optimal parameters
  - Hypothetical result
  - Gap: CNN estimation not perfect
  - Potential for further improvements, e.g. advanced CNN layouts

Results



- Outperforms the other methods
  - Other: great number of parameters with much finer granularity.
  - Our: only estimates two parameters for a 32×32 block

Results



- Possible explanation:
  - Advanced loss function
  - Can explore the actual RDT cost for the full parameter space offline
  - Trades off estimation flexibility against estimation accuracy

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- Conclusions
  - We outperform other methods although using only two parameters for large blocks
  - → Our loss function models the RDT cost accurately
  - → Might be better to optimize fewer parameters, but with an exact loss function

Thank you for your attention!

- Any questions?

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