INTRA-FRAME PREDICTION WITH LAPPED TRANSFORMS FOR IMAGE CODING

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Overview

- Motivation
- Lapped transforms: background
- Intra-frame prediction
  - Difficulties for LT
  - Proposed Solution
  - Modification in the mode selection
- Experimental Results
- Conclusion and future work

Motivation: Lapped transforms in image coding

- **Reduction of blocking effects**
- **Exploitation of redundancies among neighboring blocks**
- **Superior performance for encoding**
  - Objectively and subjectively
  - Higher complexity
- **JPEG XR**

[1] de Oliveira, R.G.; de Queiroz, R.L.; , "Intra prediction versus wavelets and lapped transforms in an H.264/AVC coder," *Image Processing, 2008. ICIP 2008. 15th IEEE International Conference on* , vol., no., pp.137-140, 12-15 Oct. 2008

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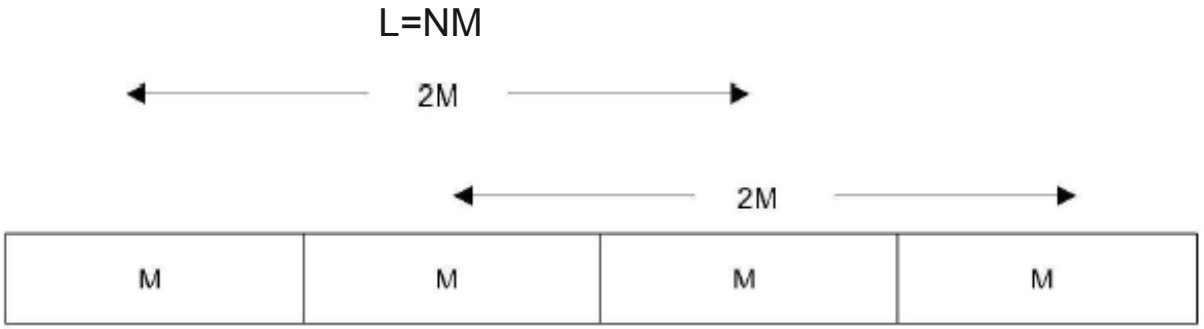
Lapped Transforms: background

- **Differently from block transforms, lapped transforms have a bigger support than the traditional block**



$$\mathbf{v_m^T} = \left[\mathbf{x}\left(\mathbf{mM} - (\mathbf{N}-1)\frac{\mathbf{M}}{\mathbf{2}}\right) \cdots \mathbf{x}\left(\mathbf{mM} - (\mathbf{N}+1)\frac{\mathbf{M}}{\mathbf{2}} - \mathbf{1}\right)\right]$$

Lapped Transforms: background

- **Direct Transform**

$$\mathbf{Y_m} = \mathbf{P} \cdot \mathbf{v_m}$$

$$\mathbf{P} = [\mathbf{P_0 P_1} \ldots \mathbf{P_{N-1}}]$$

$$\mathbf{Q} = [\mathbf{Q_0 Q_1} \ldots \mathbf{Q_{N-1}}]$$

- **Inverse Transform**

$$\hat{\mathbf{v}}_\mathbf{m} = \mathbf{Q^T} \cdot \mathbf{Y_m}$$

$$\hat{\mathbf{v}}_\mathbf{m} \neq \mathbf{v_m}$$

$$\mathbf{Q^T} \cdot \mathbf{P} \neq \mathbf{I}$$

- **Perfect reconstruction**

$$\sum_{k=0}^{N-1-m} \mathbf{Q_k^T P_{k+m}} = \sum_{\mathbf{k=0}}^{\mathbf{N-1-m}} \mathbf{Q_{k+m}^T P_k} = \delta(\mathbf{m})\, \mathbf{I_M}$$

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Lapped Transforms: reconstruction

- The blocks cannot be reconstructed independently
- The signal is reconstructed accumulating the contribution of several neighboring blocks
- Border treatment has to be carried out

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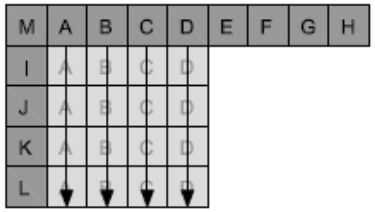
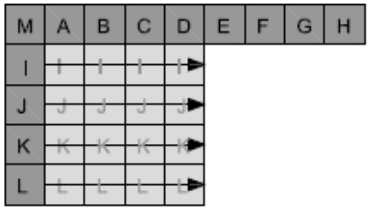
Intra-frame prediction in H.264/AVC

4x4 and
8x8 blocks



Mode 0



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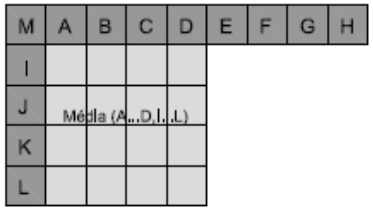

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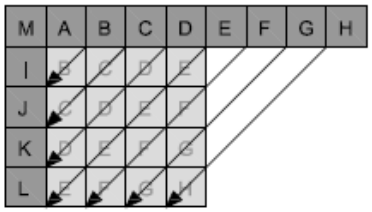

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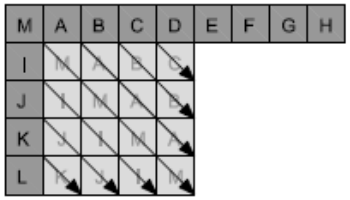

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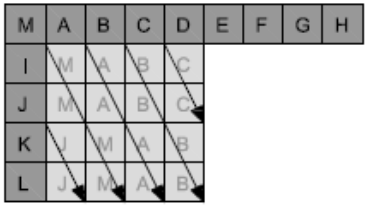

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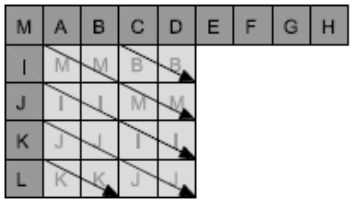
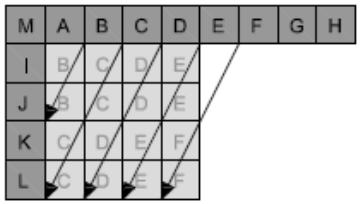
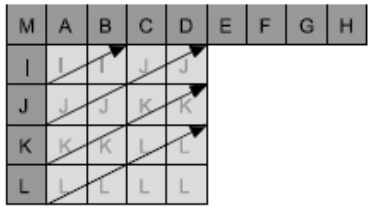


Mode 6



Mode 7

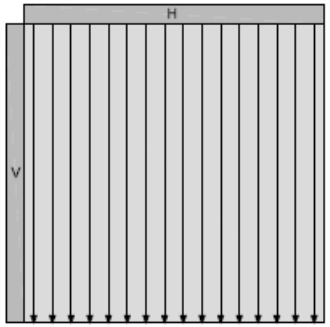


Mode 8

[2] de Queiroz, R.L.; Ortis, R.S.; Zaghetto, A.; Fonseca, T.A.; , "Fringe benefits of the H.264/AVC," *Telecommunications Symposium, 2006 International* , vol., no., pp.166-170, 3-6 Sept. 2006

Intra-frame prediction in H.264/AVC

16x16 blocks



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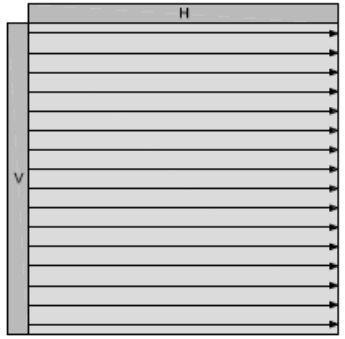
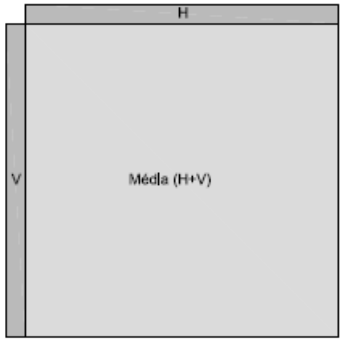


Mode 1



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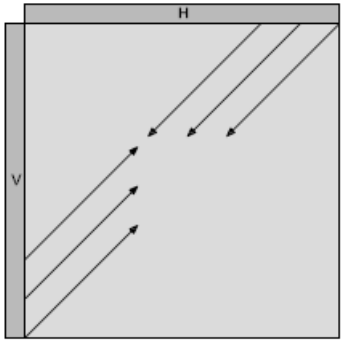
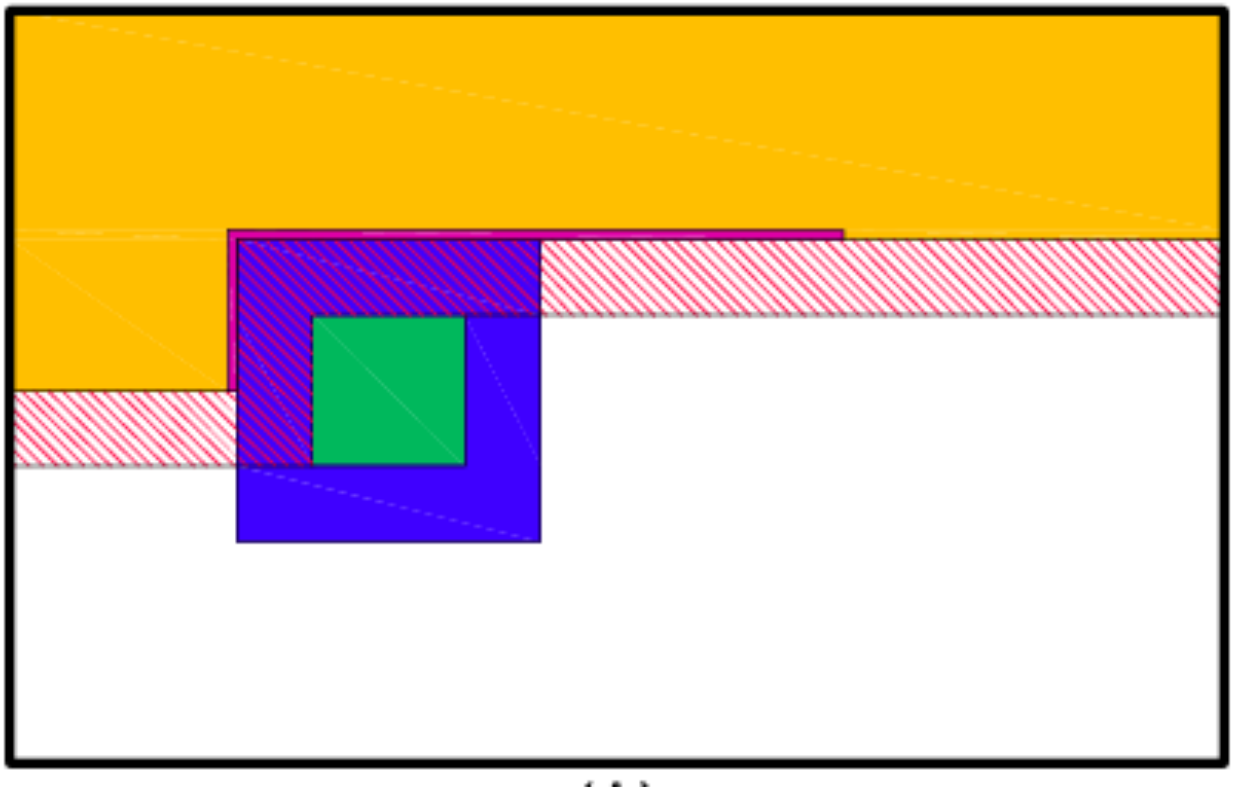
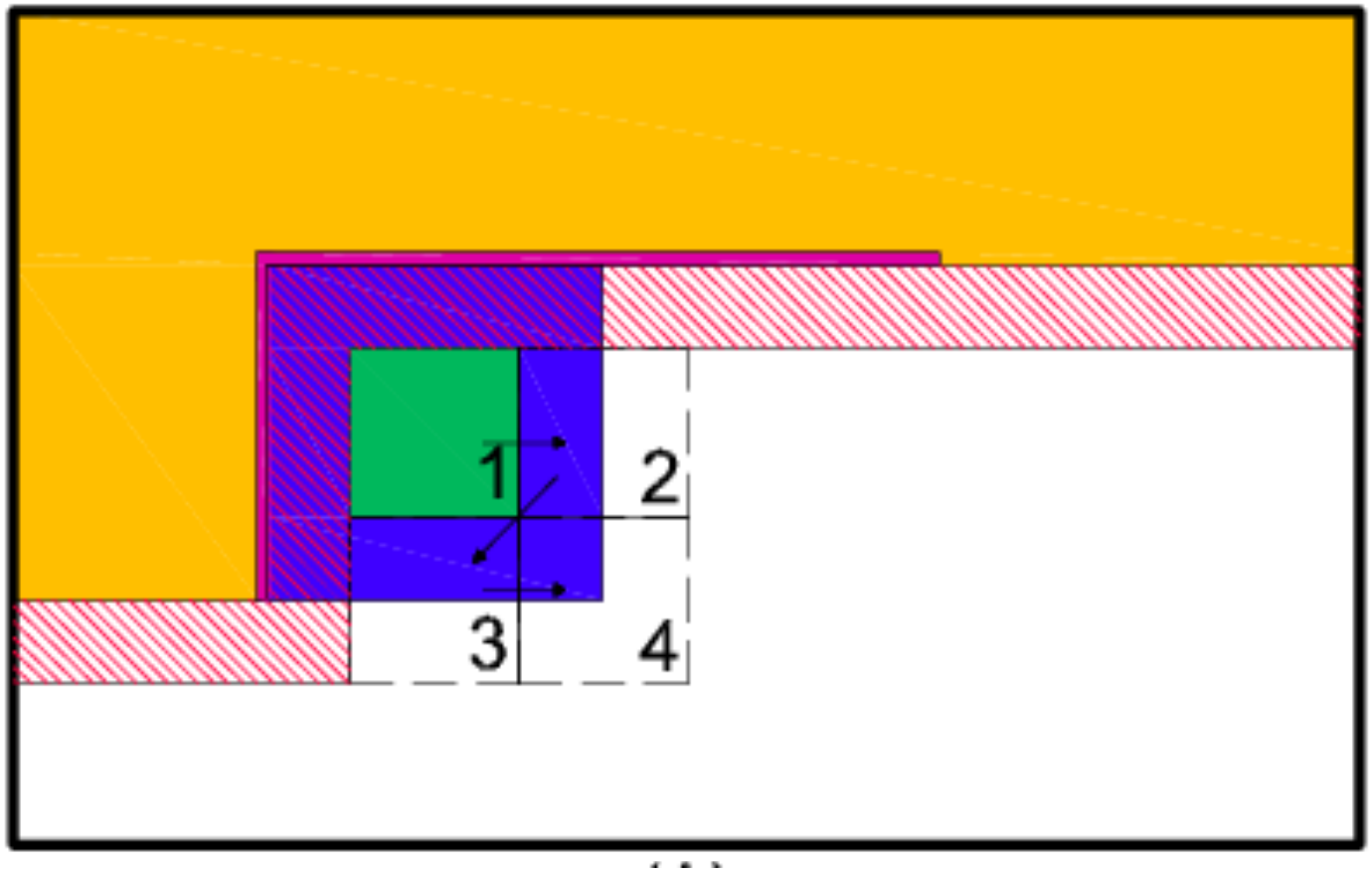


Mode 3

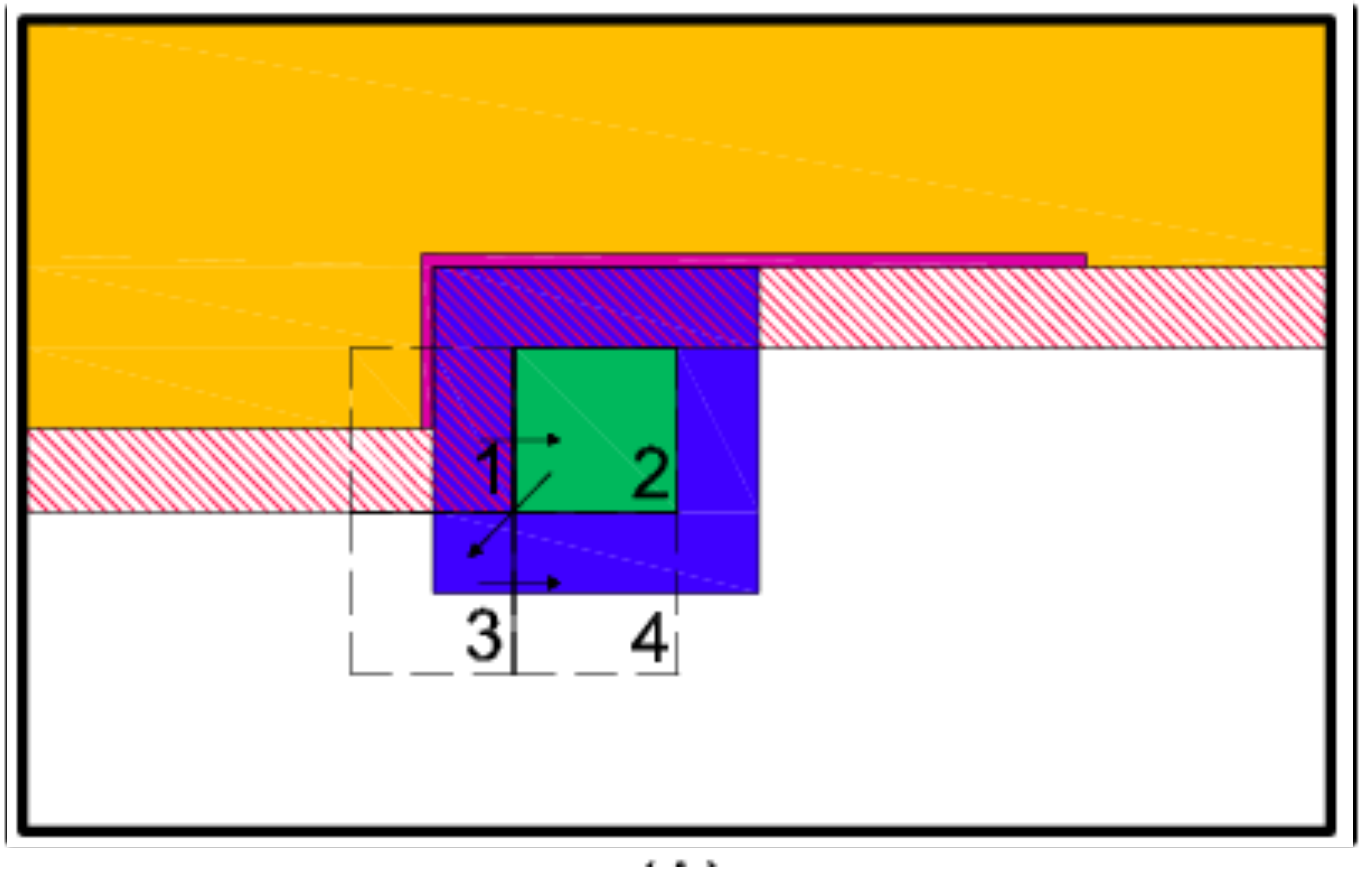
Intra frame prediction and Lapped Transforms



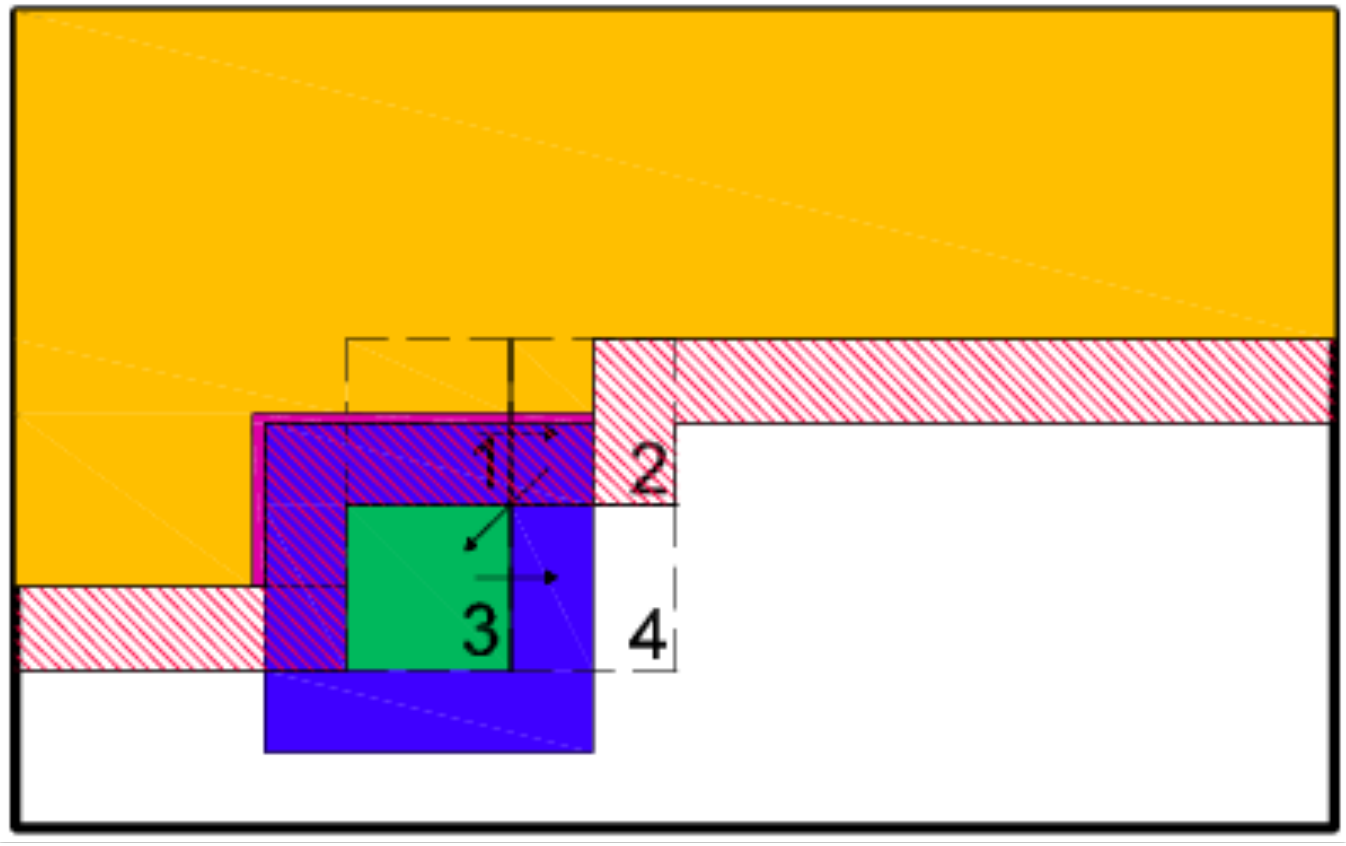
Intra frame prediction and Lapped Transforms



Intra frame prediction and Lapped Transforms



Intra frame prediction and Lapped Transforms



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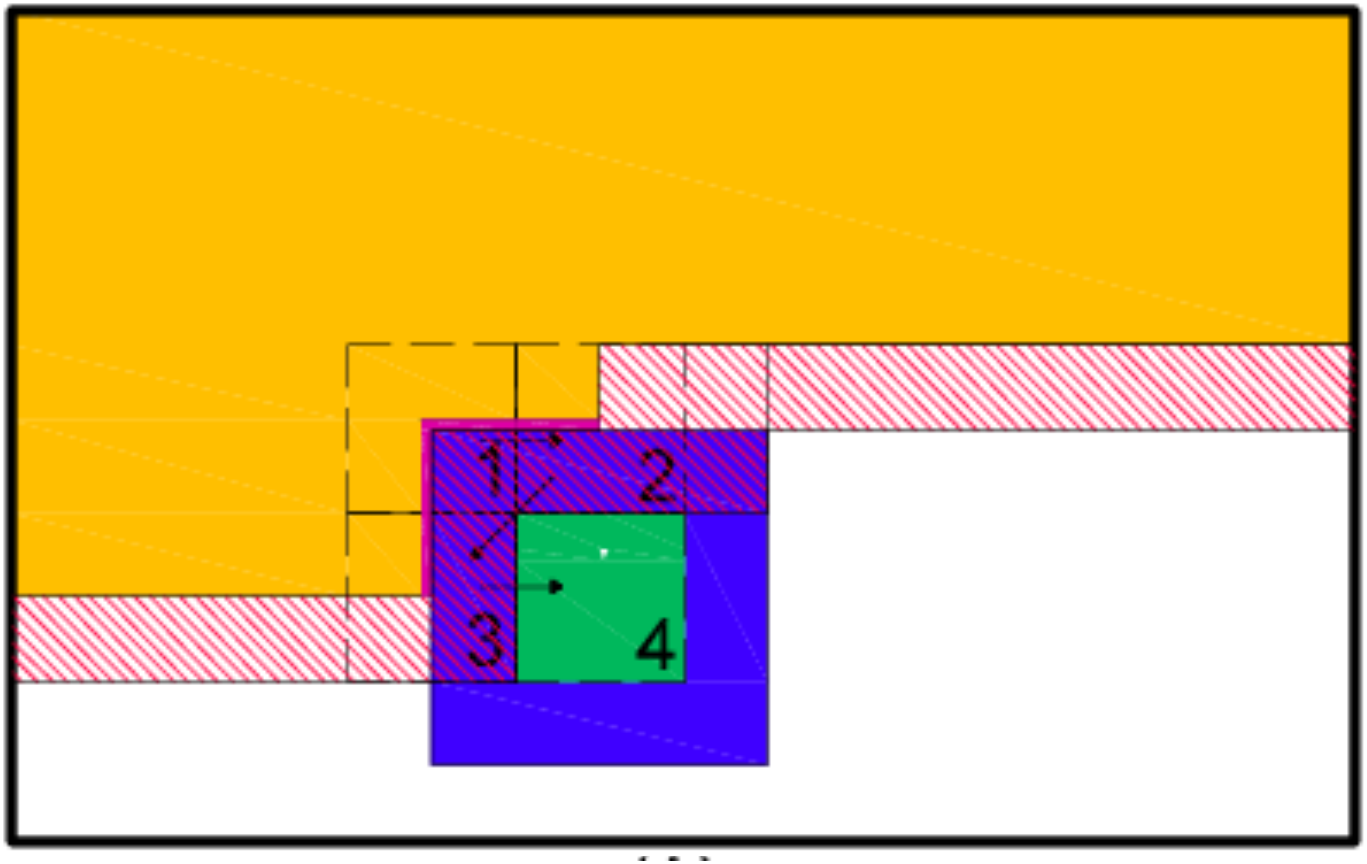
Intra frame prediction and Lapped Transforms



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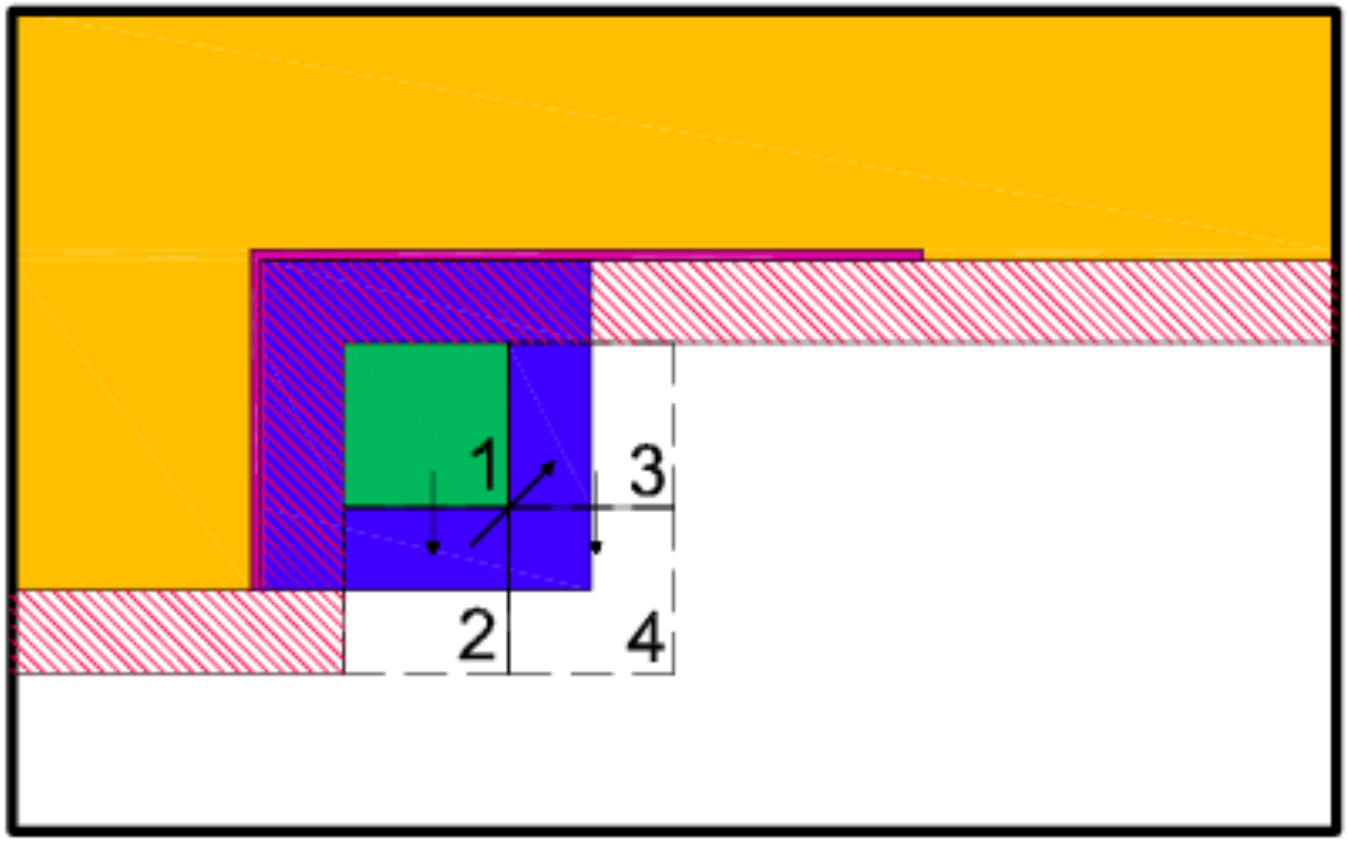
Intra frame prediction and Lapped Transforms



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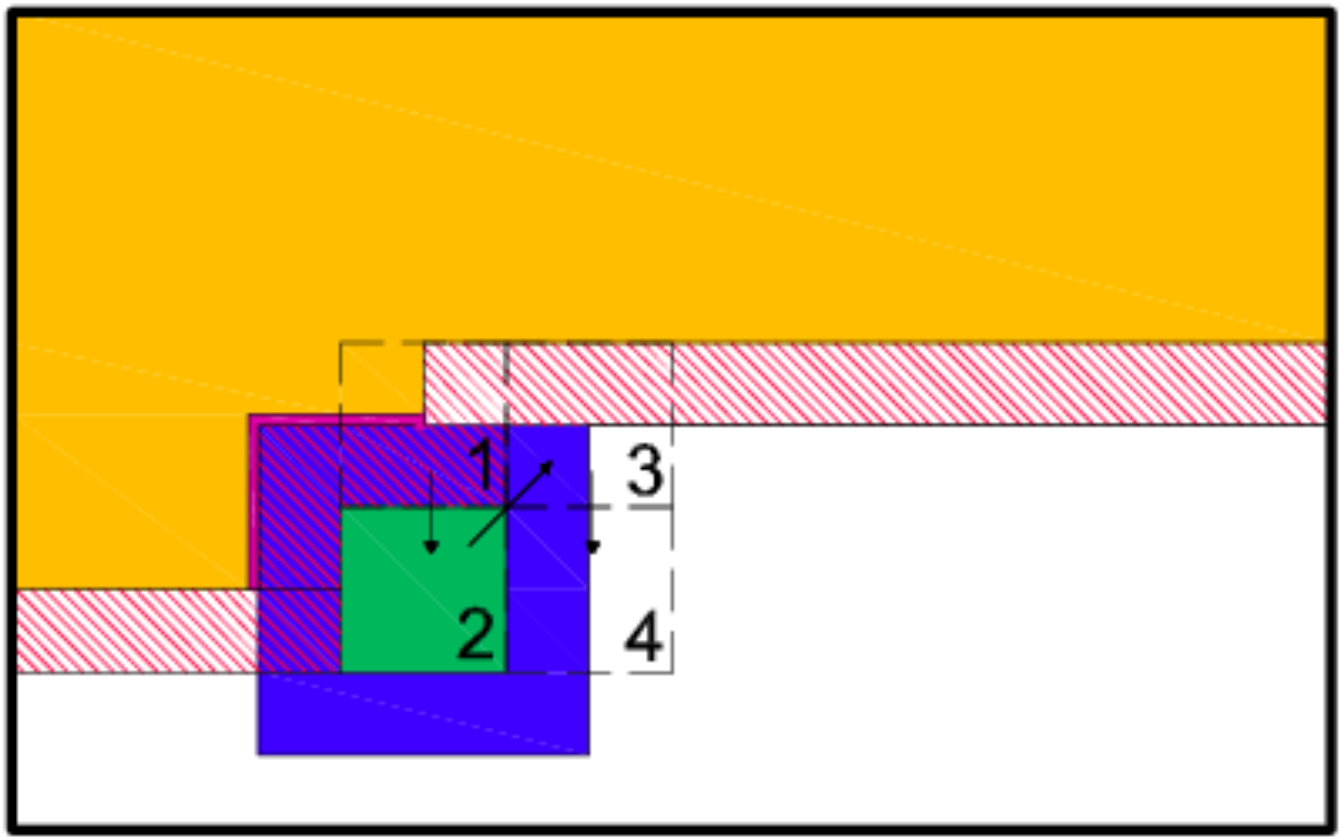
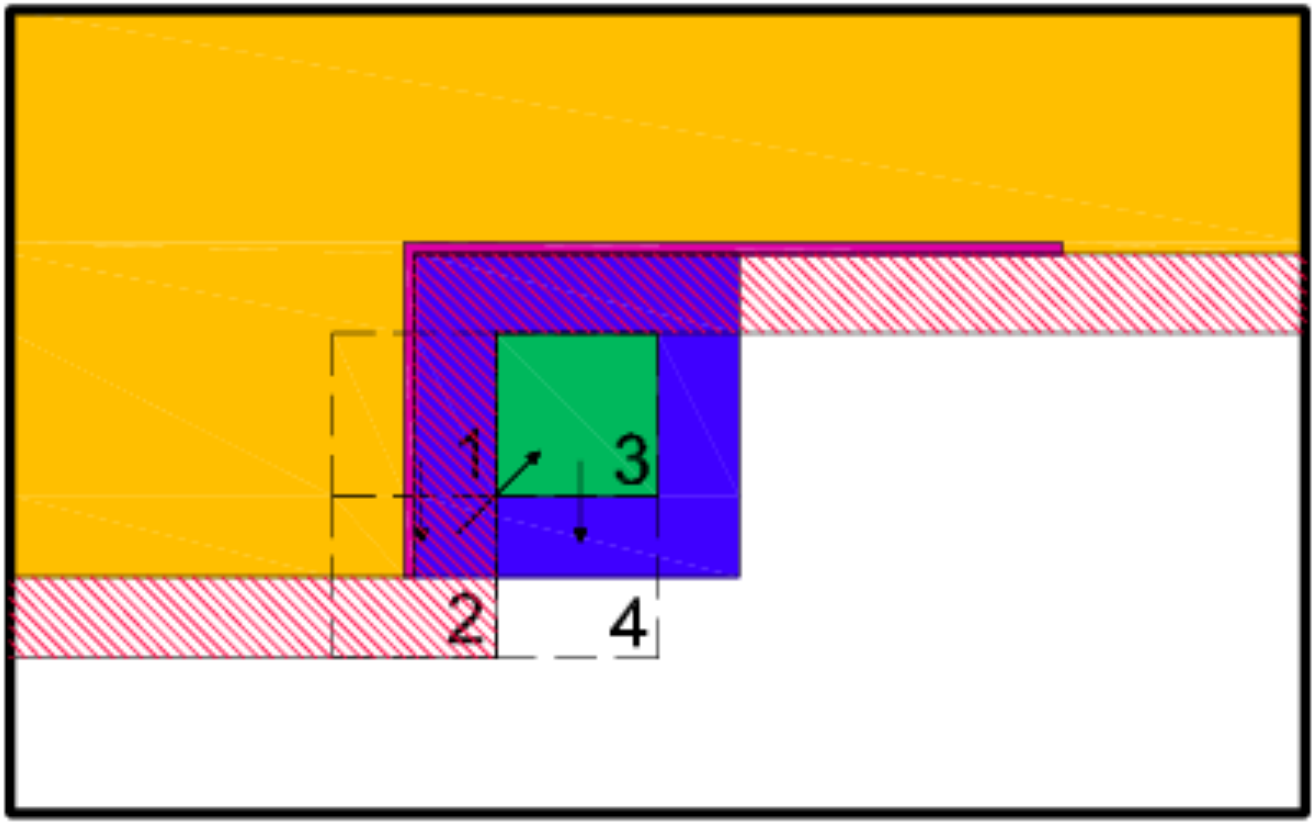
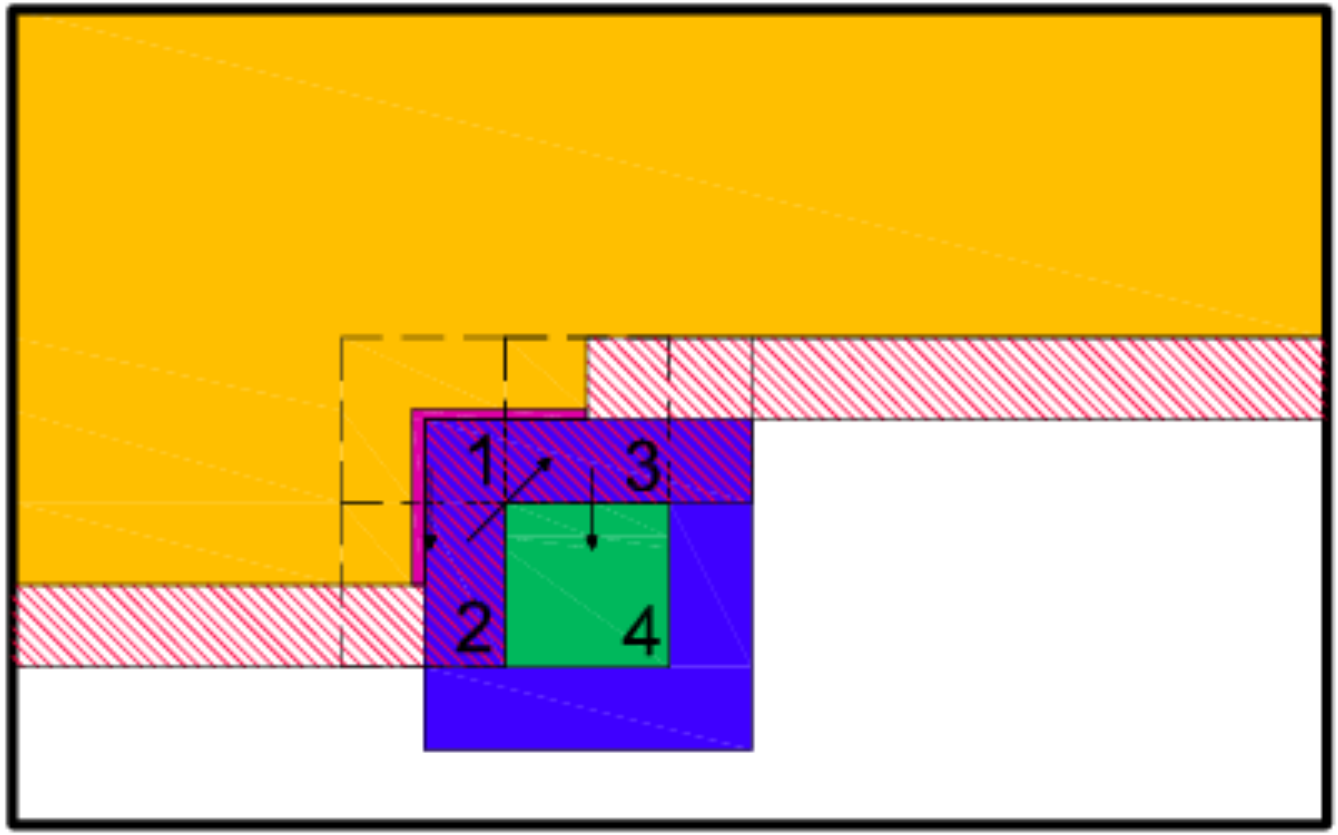
Intra frame prediction and Lapped Transforms



Intra frame prediction and Lapped Transforms



Intra frame prediction and Lapped Transforms



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Intra frame prediction and Lapped Transforms: analysis/reconstruction

- **Prediction, transform and reconstruction**

Prediction $\mathbf{R_{mn}} = \mathbf{V_{mn}} - \mathbf{Pred_{mn}}$

Direct transform $\mathbf{Y_{mn}} = \mathbf{P} \cdot \mathbf{R_{mn}} \cdot \mathbf{P^T}$

Inverse LT $\widehat{\mathbf{R}}_{\mathbf{mn}} = \mathbf{Q^T} \cdot \mathbf{Y_{mn}} \cdot \mathbf{Q}$

$$\widehat{\mathbf{V}}_{\mathbf{mn}} = \widehat{\mathbf{R}}_{\mathbf{mn}} + \mathbf{Q^T} \cdot \mathbf{P} \cdot \mathbf{Pred_{mn}} \cdot \mathbf{P^T} \cdot \mathbf{Q}$$

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Mode Selection

- **SAD**

$$SAD = \sum_{i=0}^{M-1} \sum_{j=0}^{M-1} \left| \mathbf{x}_{nm}(i,j) - \mathbf{Pred}_{nm}(i,j) \right|$$

- **WSAD**

$$WSAD = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} \left| W_{ij} \left(\mathbf{v}_{nm}(i,j) - \mathbf{Pred}_{nm}(i,j) \right) \right|$$

Weighting matrix $\mathbf{W} = \mathbf{Q}^{\mathbf{T}} \cdot \mathbf{P} \cdot \mathbf{Ones} \cdot \mathbf{P}^{\mathbf{T}} \cdot \mathbf{Q}$

- **RDO**
  - spatial reconstruction not fully available
  - distortion measure in the transform domain
  - e_{ij} is the energy of the synthesis filter

$$D = \sum_{ij} e_{ij} \left(Y_{ij} - Y'_{ij} \right)^2$$

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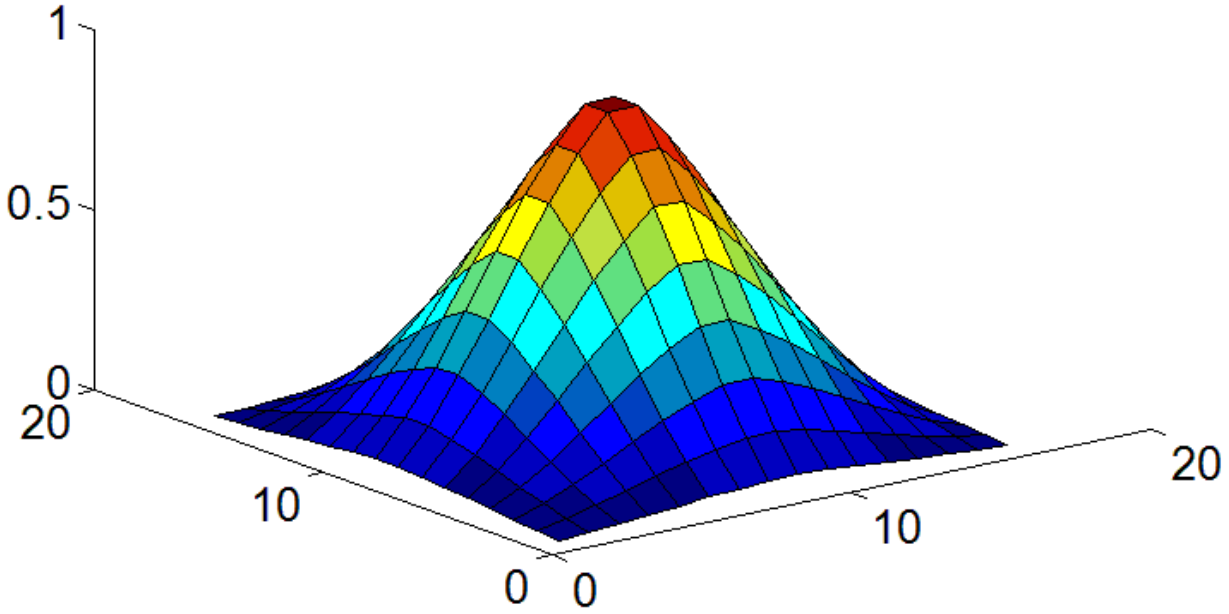
Weighting Window: example



- GLBT 8x16
- P,Q optimized for maximizing the coding gain of an AR(1) model with ρ=0.95

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Experimental results

- **Implementation has been carried in a JPEG coder**
- **The coding block fixed to 8x8 pixels**
- **Lapped transform used in the tests: GLBT 8x16**
  - Overlap of 2: more blocks benefit from the prediction
  - GLBT: best performance for this overlapping factor
  - Overlapping of 2: prediction block 16x16
  - Only four modes avaible for the prediction using LT

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Implementation Details

- **For comparison reasons, the traditional intra frame prediction was also implemented in JPEG and the modes of the traditional scheme were encoded in the same way as proposed in H.264/AVC**

- **Modes of the proposed scheme encoded using 2 bits**
  - Using the mode prediction represented a rate increase (not both neighbors available for the prediction)

- **The direct application (no prediction) of lapped transforms also tested**

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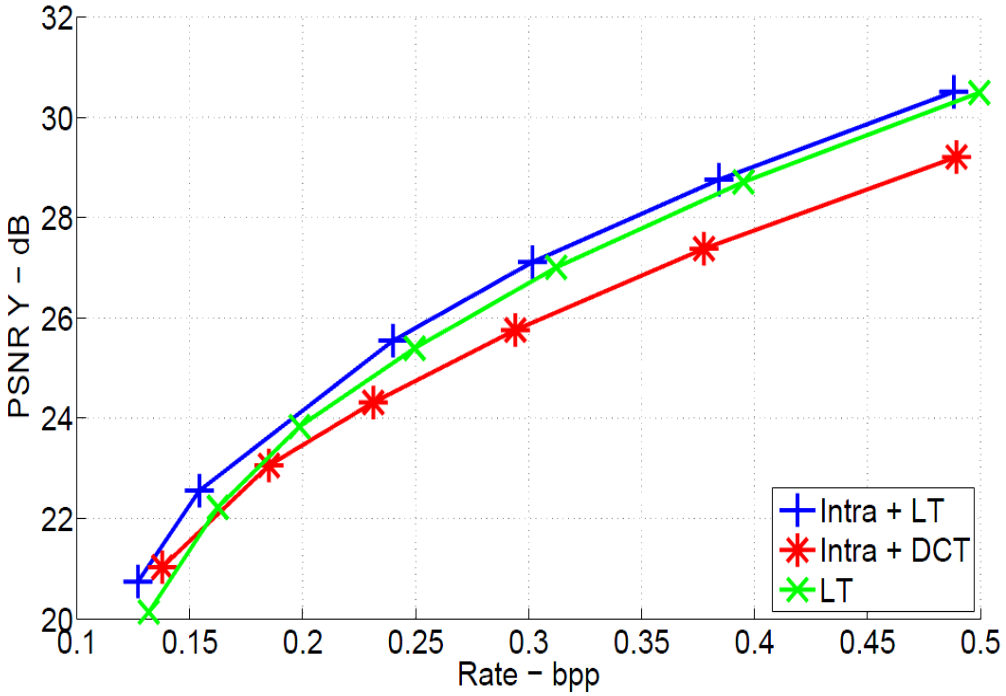
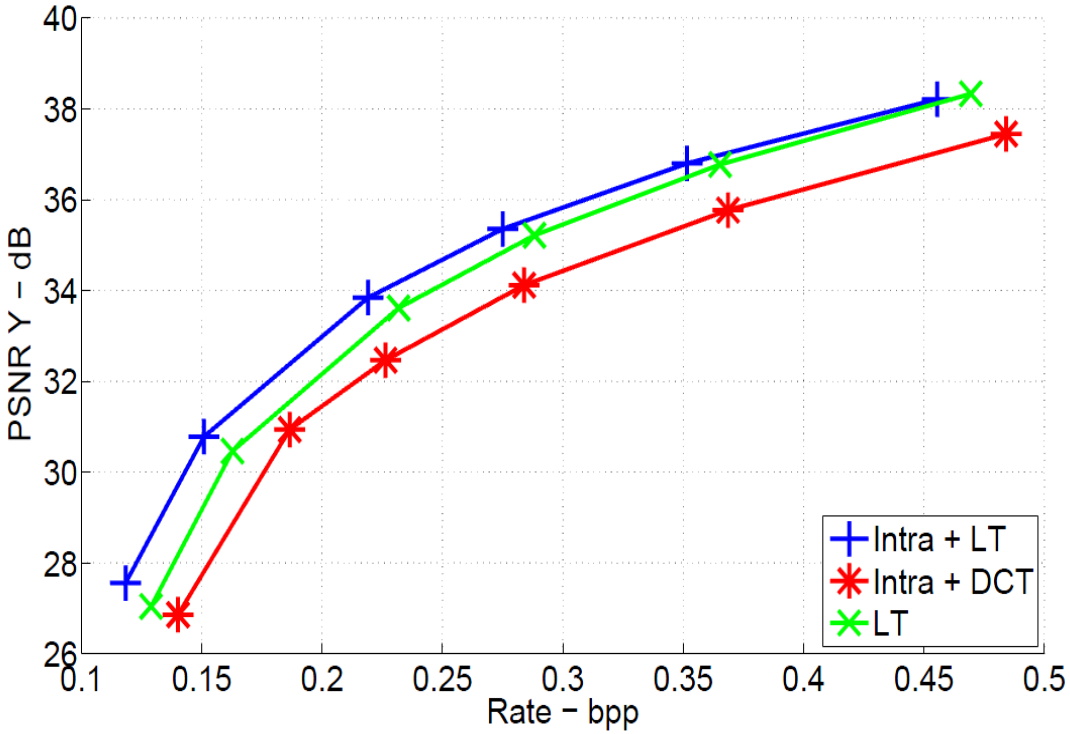
RD Results (1)

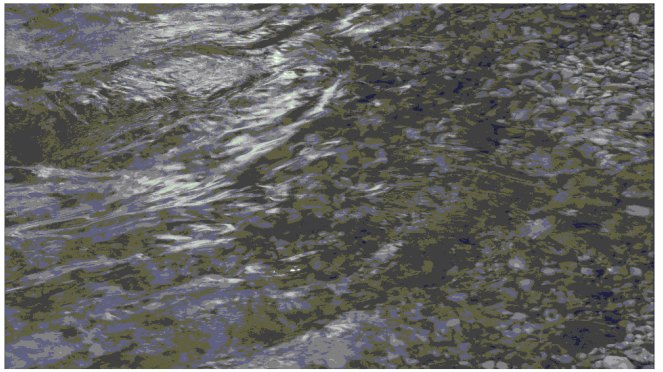
- Barbara (512x512)



RD Results (2)

- Riverbed (1920x1080) – first frame





Results: Bjontegaard metric (low bitrate)

Image (resolution)	G1(dB)	% R1	G2(dB)	% R2
Barbara (512×512)	0.79	-11.21	0.31	-3.98
Goldhill (512×512)	0.51	-8.16	0.32	-4.57
Lena (512×512)	0.40	-4.07	0.35	-3.90
Riverbed (1080p)	1.12	-14.64	0.90	-4.72
Sunflower (1080p)	1.95	-7.65	1.48	-7.02

1. Comparison between the proposed scheme and Intra-prediction with DCT
2. Comparison between the proposed scheme and the direct application of lapped transforms

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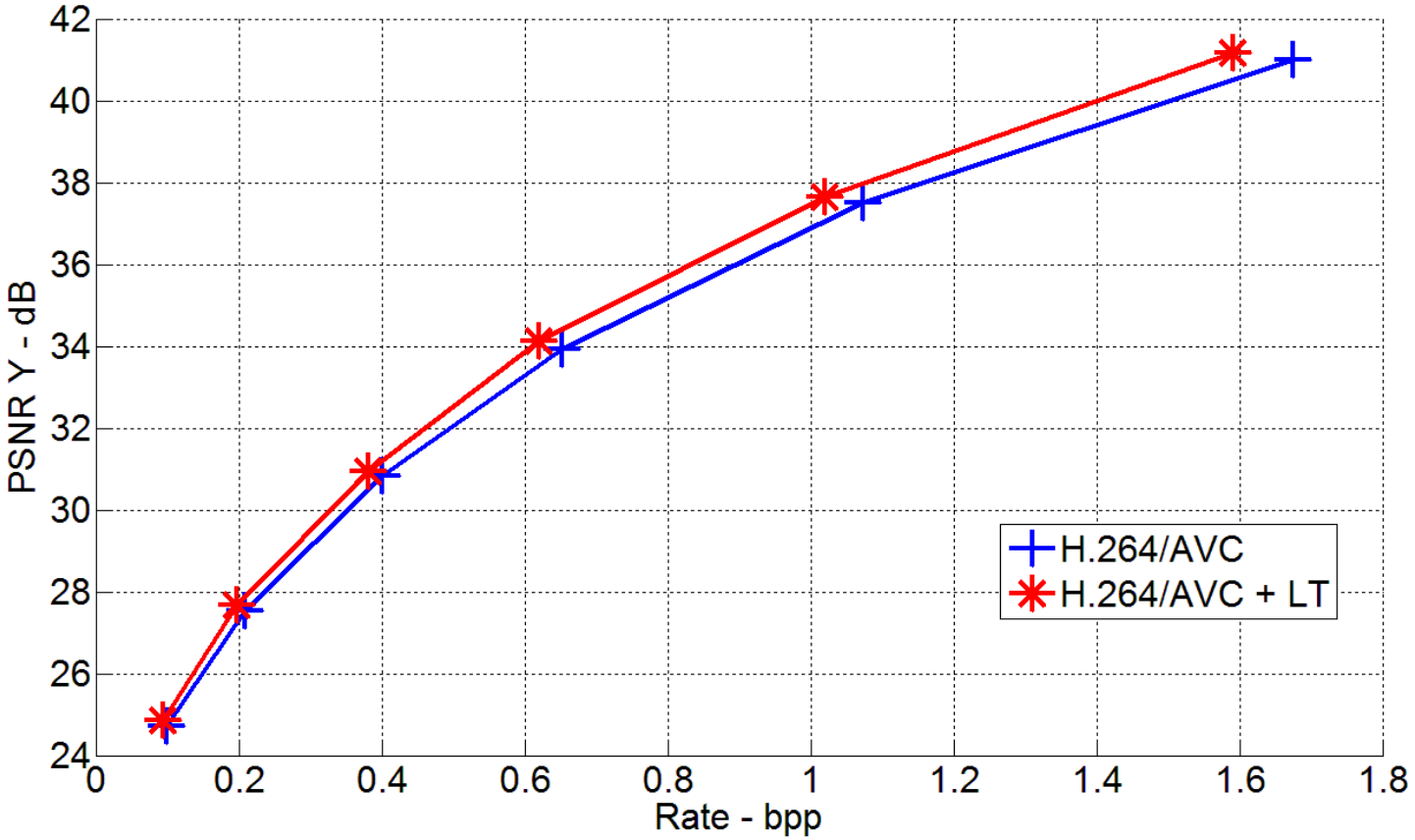
Conclusion

- The results show that intra-frame prediction can be adapted to be compatible with lapped transforms
- The proposed scheme outperforms the direct application of lapped transforms and the traditional intra prediction with DCT in all tested images
- For the moment, fewer prediction modes were implemented for 16x16 pixel blocks

Work in progress: RD Resuts(Barbara)



Work in progress

- **Implementation in H.264/AVC available for the same conditions**
  - Competition with all the prediction modes
  - CABAC adapted to the integer DCT

- **Future work**
  - Variable size prediction blocks
  - Test other transforms (with other overlapping factors)
  - A extension to video of this work has been accepted in ICIP2011

Thank you!