Improved Prediction via Thresholding Transform Coefficients

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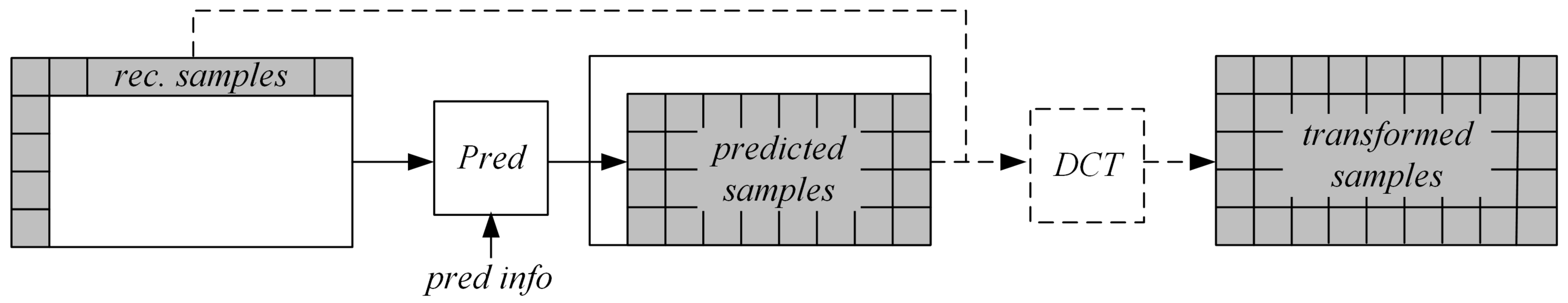
Motivation of research

Observation. A block-based video codec uses the reconstructed samples for generating a prediction. When transformed via DCT, the signal tends to be concentrated in a few low-frequency components.

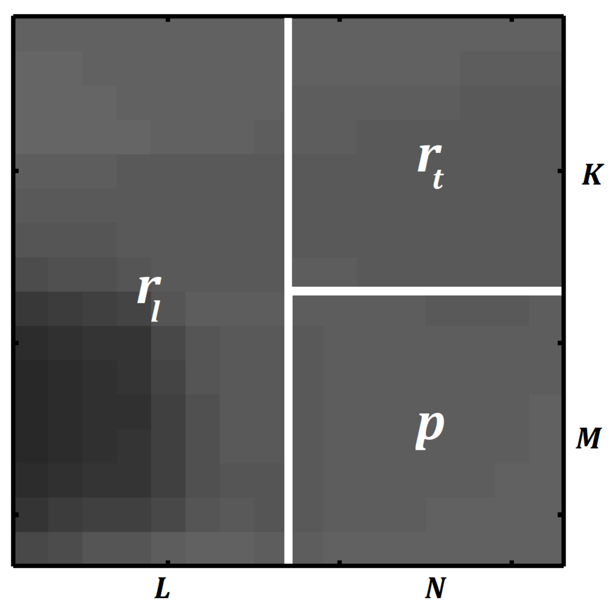


Compressed sensing theory. Assume a high-dimensional signal has a sparse representation in a suitable basis. Then it can be recovered from incomplete or distorted data by random linear measurements.

A question to answer. Is it possible to restore the original samples from the prediction by sparse regularization in the transform domain?

Description of the thresholding method

Initial value. Let $p \in \mathbb{R}^{M\times N}$ be the initial luma prediction. Let r_t and r_l be the reconstructed samples in the $K \leq M$ rows above and the $L \leq N$ columns to the left. Define the extended prediction $y \in \mathbb{R}^{(M+K)\times(N+L)}$ by arranging as below.



Forward transform. Map into the frequency domain via the orthogonal discrete cosine transform $W : \mathbb{R}^{(M+K)\times(N+L)} \to \mathbb{R}^{(M+K)\times(N+L)}$

$$Y = Wy. \tag{1}$$

Thresholding. Choose a threshold value $\tau > 0$. Set transform coefficients $Y_{11}, ..., Y_{(M+K),(N+L)}$ whose absolute value is less than the threshold τ to zero. Hence, the thresholded coefficients are given by

$$\hat{Y}_{ij} = \begin{cases} Y_{ij} & |Y_{ij}| \geq \tau \\ 0 & \text{otherwise} \end{cases}. \tag{2}$$

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Inverse transform. Use the inverse DCT and compute the new extended prediction signal $\hat{y} \in \mathbb{R}^{(M+K)\times(N+L)}$ as

$$\hat{y} = W^T\hat{Y}. \tag{3}$$

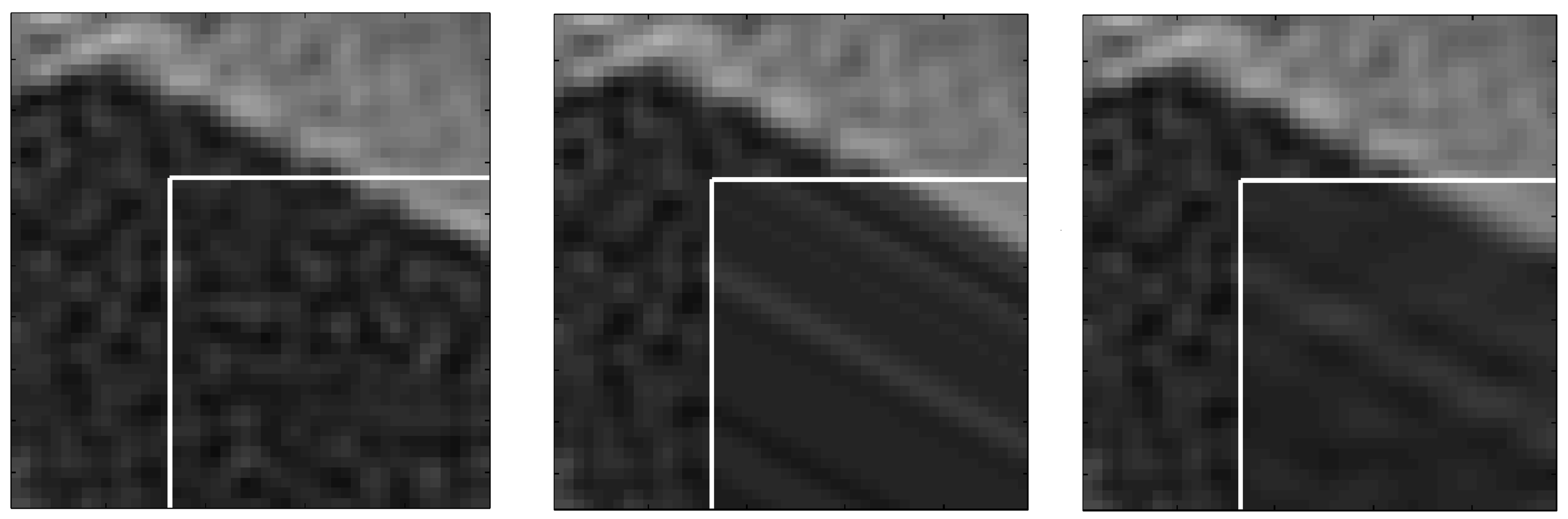
The existing prediction p is then replaced by the modified prediction $\hat{p} \in \mathbb{R}^{M\times N}$ whose entries for $i = 1, ..., M$ and $j = 1, ..., N$ are

$$\hat{p}_{ij} = \hat{y}_{(i+K),(j+L)}. \tag{4}$$

Sparse regularization.

- Goal: Force the prediction to have sparse transform coefficients in accordance with the reconstructed neighborhood.
- Impact of the neighborhood: The coding gain vastly decreases when the reconstructed samples are not used (experimentally validated).
- Choice of the threshold: Different values of τ need to be tested. Take into account the range of the transform coefficients Y and the QP.

Example



Left: Original luma samples. Middle: Angular prediction with extended boundary. Right: Result of the thresholding method.

Thresholding modes

Thresholding mode	Type	Nr. of thresholds τ	Nr. of extension sizes (K, L)
0	no thresholding	-	-
1	use thresholding	8	4

The thresholds are set as table values, depending on the QP.
The extension sizes are set as table values as well.

Experimental results in HEVC

- High-Tier, QP $\in \{22, 27, 32, 37\}$:

All Intra

Sequence name	Resolution	Y
BasketballDrive	HD	-3.92%
Tango	4K UHD	-4.90%
Rollercoaster	4K UHD	-5.17%
Crosswalk	4K UHD	-6.61%
FoodMarket	4K UHD	-8.04%
Overall		**-5.73%**

Random Access

Sequence name	Resolution	Y
Nebuta	4K UHD	-5.37%
Tango	4K UHD	-4.10%
Rollercoaster	4K UHD	-3.73%
Crosswalk	4K UHD	-4.43%
FoodMarket	4K UHD	-4.47%
Overall		**-4.42%**

- Main-Tier, QP $\in \{27, 32, 37, 42\}$:

All Intra

Sequence name	Resolution	Y
BasketballDrive	HD	-4.52%
Tango	4K UHD	-5.02%
Rollercoaster	4K UHD	-5.55%
Crosswalk	4K UHD	-6.79%
FoodMarket	4K UHD	-7.93%
Overall		**-5.96%**

Random Access

Sequence name	Resolution	Y
Nebuta	4K UHD	-5.81%
Tango	4K UHD	-3.02%
Rollercoaster	4K UHD	-2.98%
Crosswalk	4K UHD	-3.39%
FoodMarket	4K UHD	-3.25%
Overall		**-3.69%**

RD plot of *Food Market*, All Intra