# Quantization noise reduction in hybrid video coding by a system of three adaptive filters

## Picture Coding Symposium 2010

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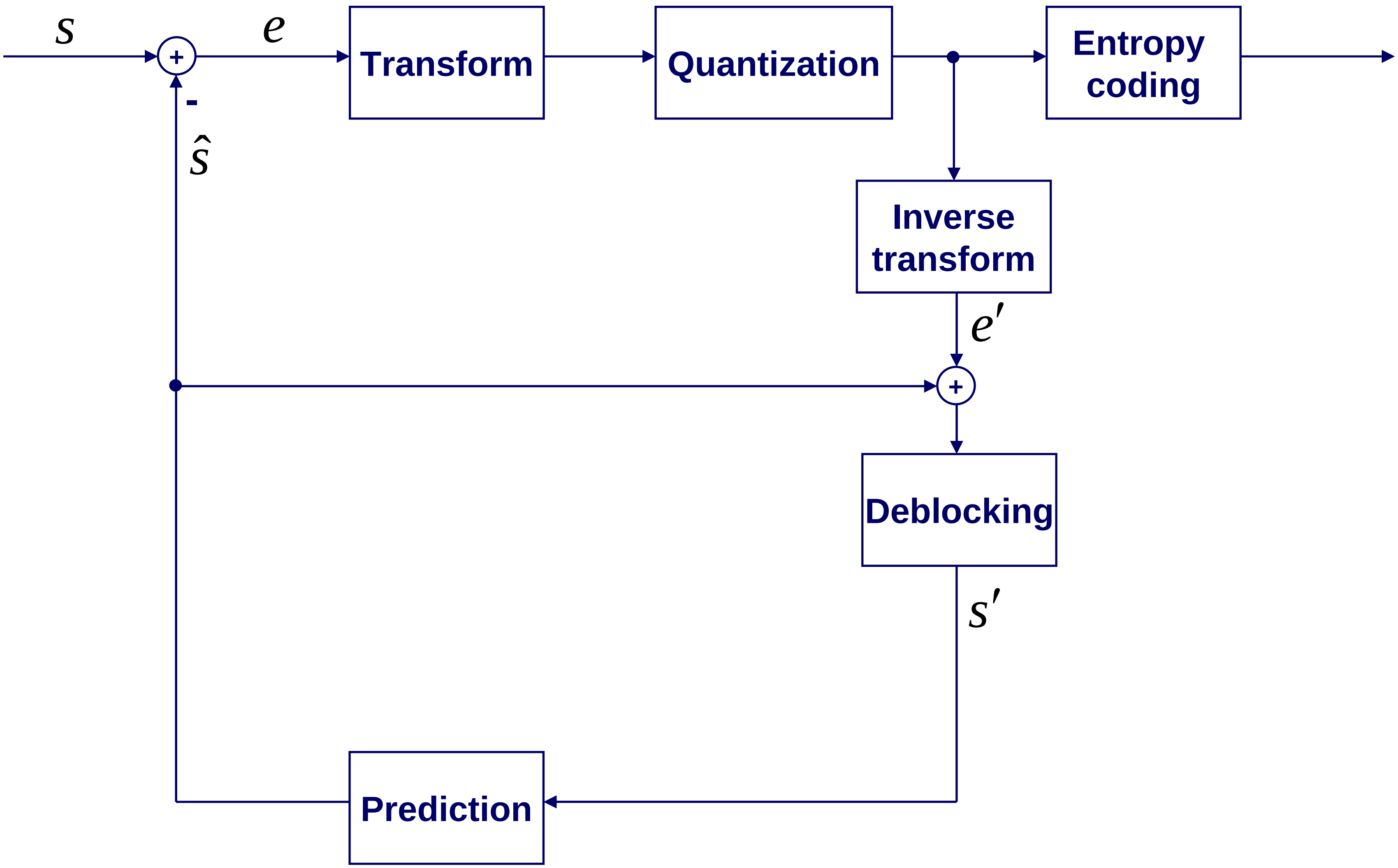
# Outline

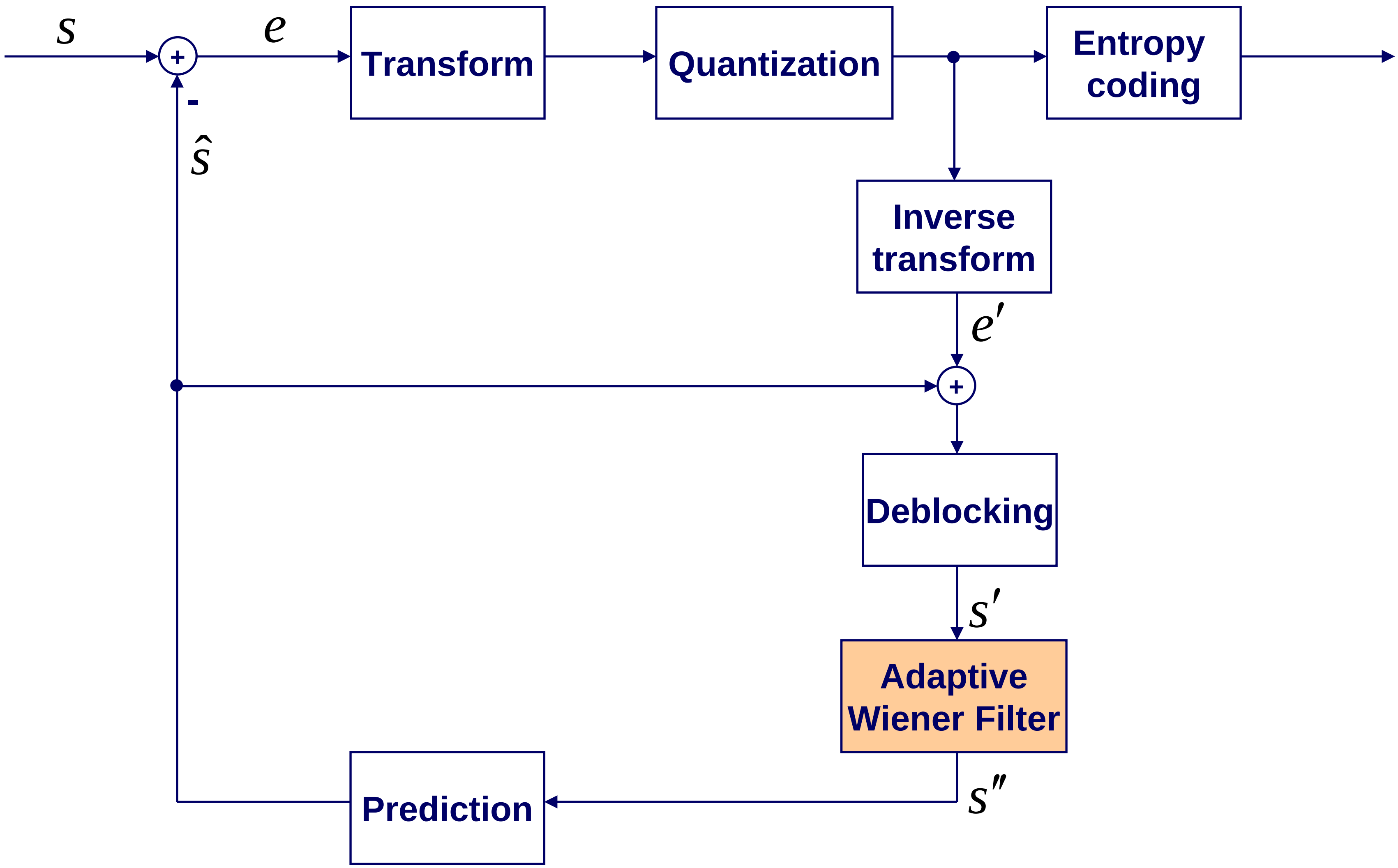
- Introduction
- Quantization noise reduction by a system of three adaptive filters
- Experiments and results
- Conclusion

# Block diagram of a standardized hybrid coder




Reconstruction error: $q_1 = s' - s$

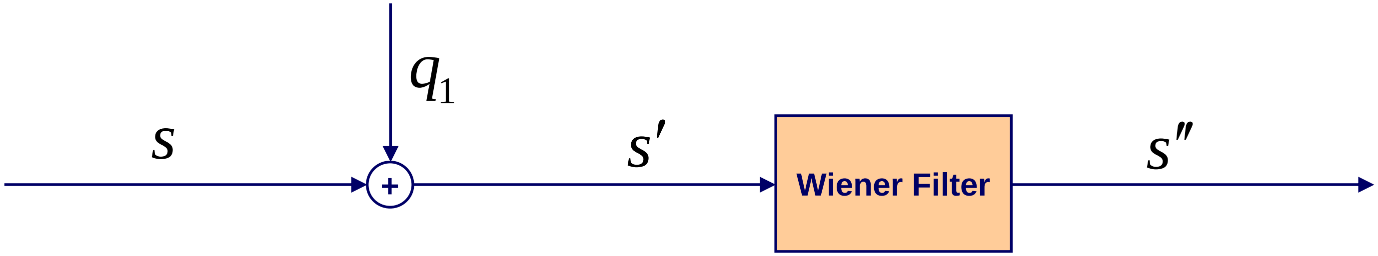
# Block diagram of a hybrid coder applying an adaptive Wiener filter to reduce the mean squared reconstruction error




**S. Wittmann, T. Wedi, "Transmission of Post-Filter Hints for Video Coding Schemes", Proc. IEEE International Conference on Image Processing (ICIP 2007), San Antonio, Texas, USA, September 2007**

# Wiener filter

- Assumption:
  Input signal $s$ is superposed by additive noise $q_1$




- Filter operation: $s'' = \sum_{l=1}^{L} a_l \cdot s'_l + o$

- Estimation of Wiener filter coefficients by minimization of mean squared reconstruction error

$$E\left[(s - s'')^2\right] \rightarrow \min$$

# Estimation of Wiener filter coefficients

- Setting all partial derivations to zero

$$\frac{\partial}{\partial a_l} E\left[(s - s'')^2\right] = 0, \qquad l = 1, \ldots, L \qquad\qquad \frac{\partial}{\partial o} E\left[(s - s'')^2\right] = 0$$

- Solving the resulting system of $L+1$ equations

$$\begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_L \\ o \end{bmatrix} = \begin{bmatrix} E[s_1' \cdot s_1'] & E[s_1' \cdot s_2'] & \cdots & E[s_1' \cdot s_L'] & E[s_1'] \\ E[s_2' \cdot s_1'] & \ddots & & \vdots & E[s_2'] \\ \vdots & & \ddots & & \vdots \\ E[s_L' \cdot s_1'] & \cdots & & E[s_L' \cdot s_L'] & E[s_L'] \\ E[s_1'] & E[s_2'] & \cdots & E[s_L'] & 1 \end{bmatrix}^{-1} \cdot \begin{bmatrix} E[s \cdot s_1'] \\ E[s \cdot s_2'] \\ \vdots \\ E[s \cdot s_L'] \\ E[s] \end{bmatrix}$$

- Since $s' = s + q_1$, the filter coefficients depend on the noise $q_1$

# Features of the Adaptive Wiener Filter

- Coefficients are estimated individually for each frame
- Estimated coefficients are coded and transmitted together with each frame

# Motivation

- **State of the art**
  Reduction of the mean squared reconstruction error by applying an adaptive Wiener filter adjusted to the noise of the deblocked signal

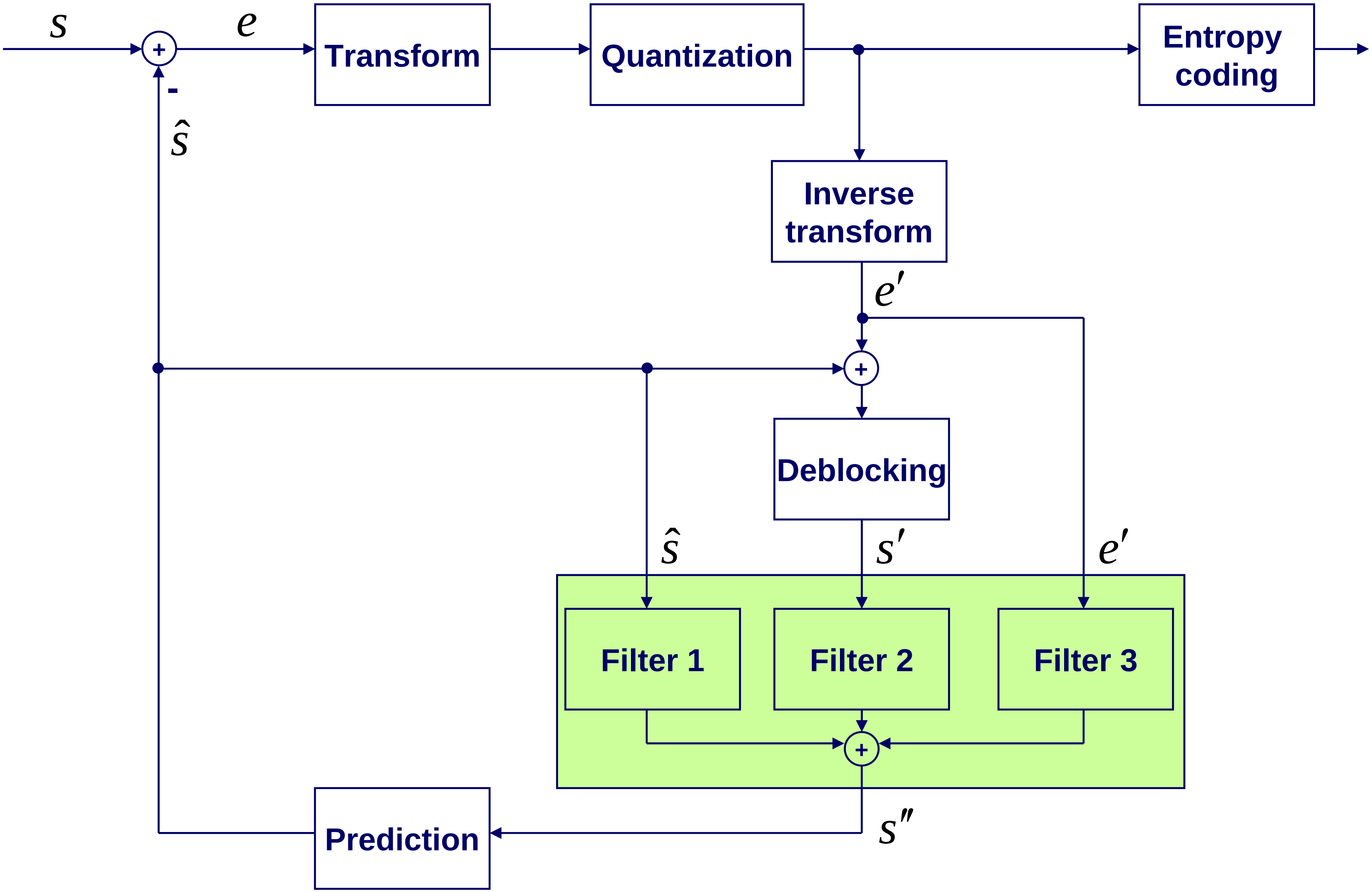
- **Problem**
  The deblocked signal contains the two components prediction and quantized prediction error. The noise of these two components is different from the noise of the deblocked signal itself:

  - Noise of deblocked signal is the reconstruction error: $s = s' + q_1$
  - Noise of prediction signal is the prediction error: $s = \hat{s} + q_2$
  - Noise of quantized prediction error signal is the quantization error: $e = e' + q_3$

  The knowledge of these three individual noise sources is currently not exploited

- **Approach**
  To each of the deblocked signal, prediction signal, and quantized prediction error signal, an individual filter is applied

# Block diagram of the extended hybrid coder



# System of three adaptive filters

- Filter operations:

$$s'' = \sum_{l=1}^{L} a_l \cdot s'_l + \sum_{m=1}^{M} b_m \cdot \hat{s}_m + \sum_{n=1}^{N} c_n \cdot e'_n + o$$

- Estimation of filter coefficients by minimization of mean squared reconstruction error

$$E\left[\left(s - s''\right)^2\right] \rightarrow \min$$

# Estimation of filter coefficients

- Setting all partial derivations to zero

$$\frac{\partial}{\partial a_l} E\left[(s - s'')^2\right] = 0, \qquad l = 1, \ldots, L$$

$$\frac{\partial}{\partial b_m} E\left[(s - s'')^2\right] = 0, \qquad m = 1, \ldots, M$$

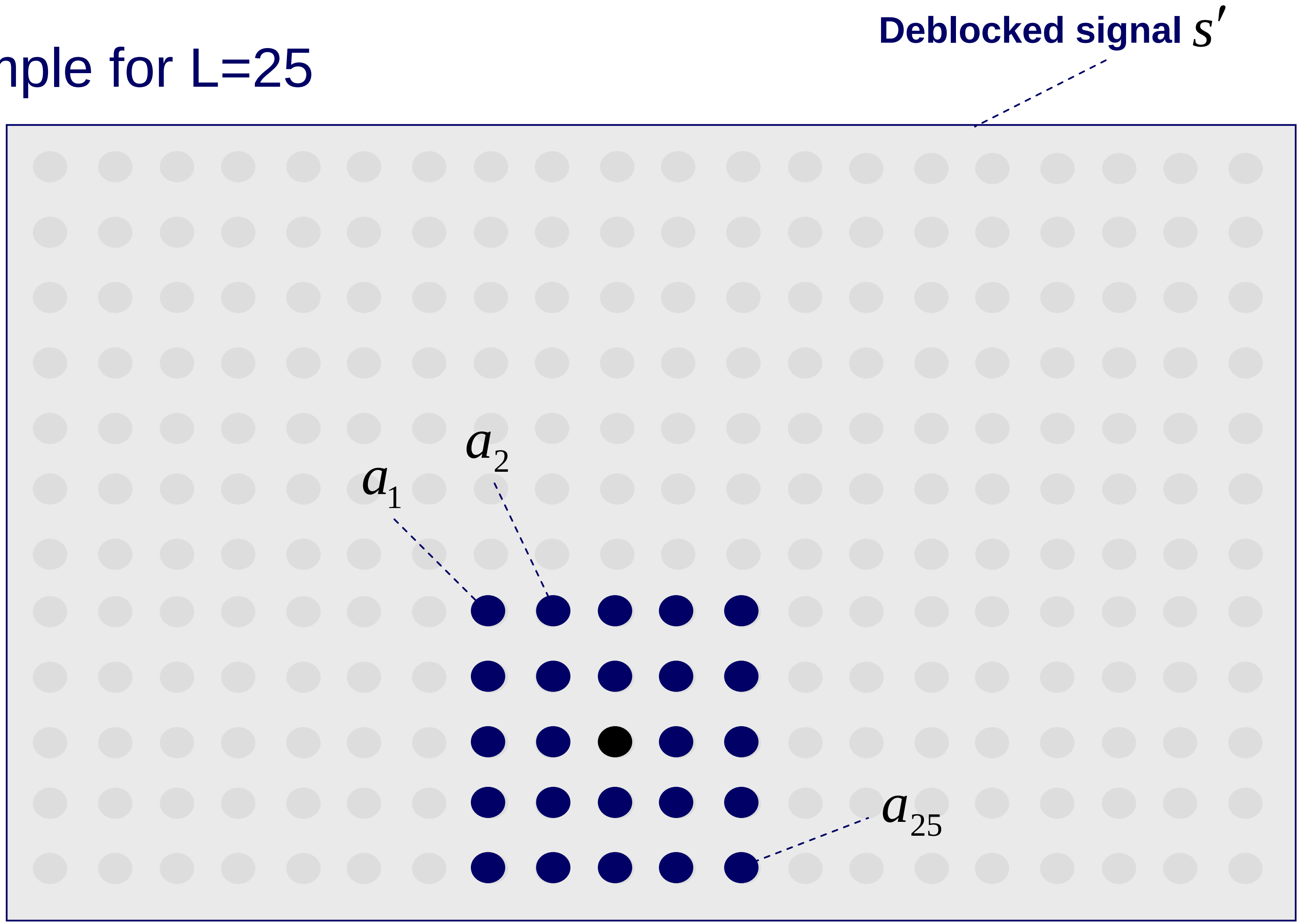
$$\frac{\partial}{\partial c_n} E\left[(s - s'')^2\right] = 0, \qquad n = 1, \ldots, N$$

$$\frac{\partial}{\partial o} E\left[(s - s'')^2\right] = 0$$

- Solving the resulting system of $L + M + N + 1$ equations

# Filter shapes

- All three filters have a squared shape
- Example for L=25



# Selection of filter sizes

- Selection of filter sizes L, M, and N according to minimum Lagrangian costs of
  - Mean squared reconstruction error
  - Bit rate

- Considered filter sizes for each of L, M, N
  - 1 (1x1)
  - 9 (3x3)
  - 25 (5x5)
  - 49 (7x7)
  - 81 (9x9)

# Coding of estimated filter coefficients

- Uniform quantization

- Binary arithmetic coding of
  - Selected filter sizes L, M, and N
  - Quantized estimated coefficients

# Implementation

- Implemented in the hybrid coder proposed to the JCT-VC as a response to the call for proposals from ISO/IEC and ITU-T

I. Amonou, et. al., “Description of video coding technology proposal by France Telecom, NTT, NTT DOCOMO, Panasonic and Technicolor”, Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11 Document JCT-VC A114, 1st Meeting: Dresden, Germany, 15-23 April, 2010

Ranking in the evaluation of all 27 responses to the call for proposal:

- Within a cluster of the 5 proposals of highest coding efficiency

# Experiments

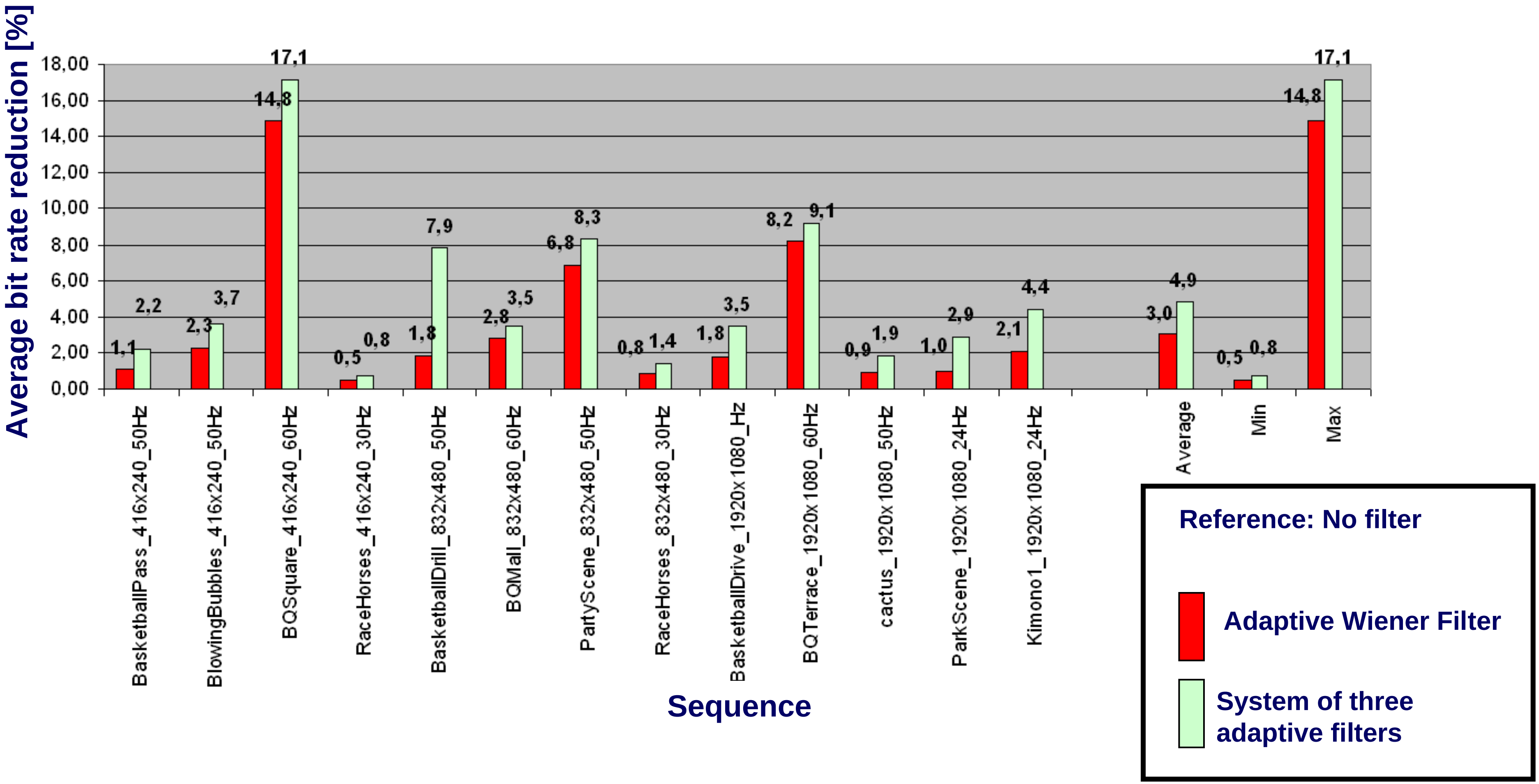
- Reference: Hybrid coder applying no adaptive filter
- Tested
  - Adaptive Wiener Filter
  - System of three adaptive filters
- Test conditions
  - According to

    ITU-T Q6/16 Visual Coding and ISO/IEC JTC1/SC29/WG11 Coding of Moving Pictures and Audio, „Joint Call for Proposals on Video Compression Technology", ITU-T Q6/16 doc. VCEG-AM91, Kyoto, Japan, January 2010

  - Prediction structure using 7 hierarchical B-Frames
  - First 2 second of 13 sequences
  - 4 different quantization step sizes for each sequence
  - For each frame
    - Filter coefficients are estimated, coded, and transmitted
    - Filter sizes are selected, coded, and transmitted
- Calculation of average bit rate reduction at the same quality according to

  G. Bjontegaard, „Improvements of the BD-PSNR model", ITU-T Q6/16 doc. VCEG-AI11, Berlin, Germany, July 2008

# Results of experiments




- Average bit rate reduction by the system of three adaptive filters: 4.9% (More than 1.6 times higher than the one of the adaptive Wiener filter)
- For particular sequences: Bit rate reduction of up to 17.1%

# Summary

- Noise reduction by a system of three adaptive filters exploiting the knowledge of three different noise sources
  - Noise of deblocked signal
  - Noise of prediction signal
  - Noise of quantized prediction error signal
- Filter coefficients and filter sizes are estimated, coded and transmitted for each frame
- Results of experiments
  - Average bit rate reduction at the same quality: 4.9%
  - For particular sequences: Up to 17.1%
- Application
  - Adoption into test model under consideration of ISO/IEC and ITU-T
  - Under consideration for a new video coding standard