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Motion-Compensated Orthogonal Transforms for Multiview Video Coding

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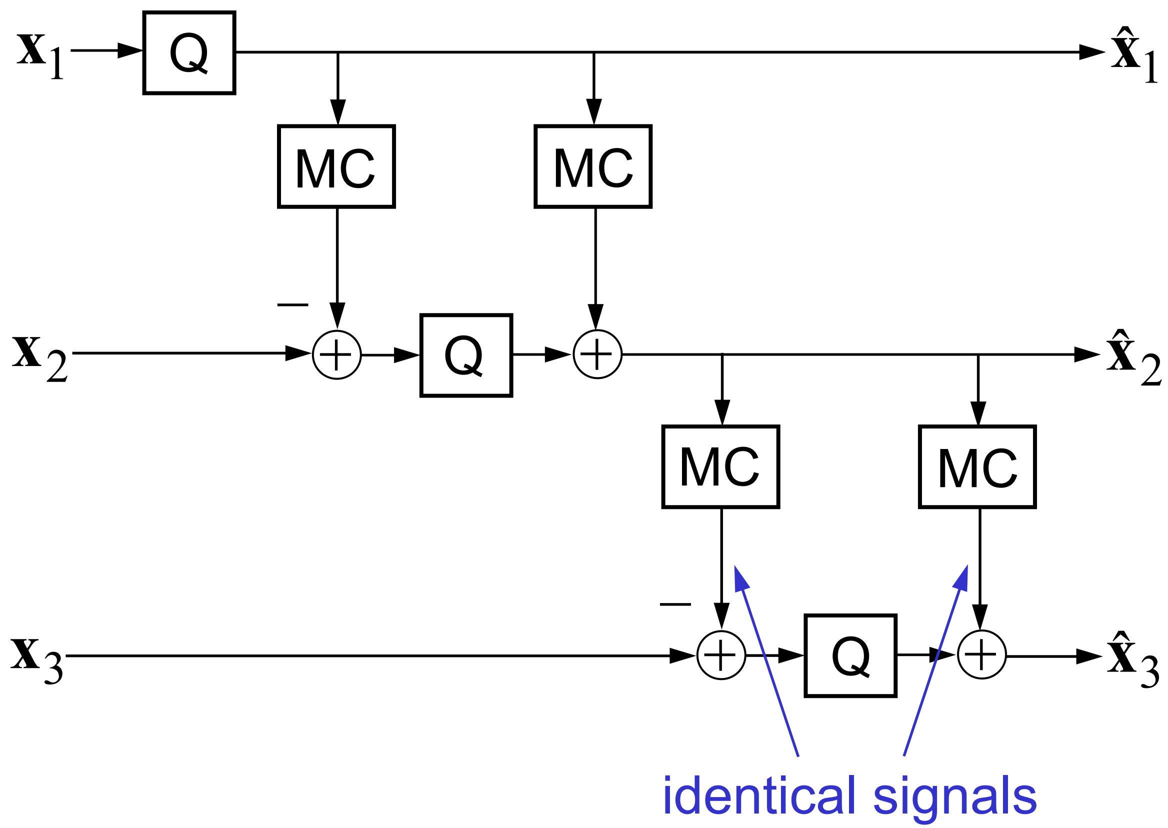
Outline

- Coding of multiview video
- Limitations of adaptive lifted wavelets
- Concept of adaptive orthogonal transforms
- Class of adaptive orthogonal transforms
- Experimental results
- Demonstration

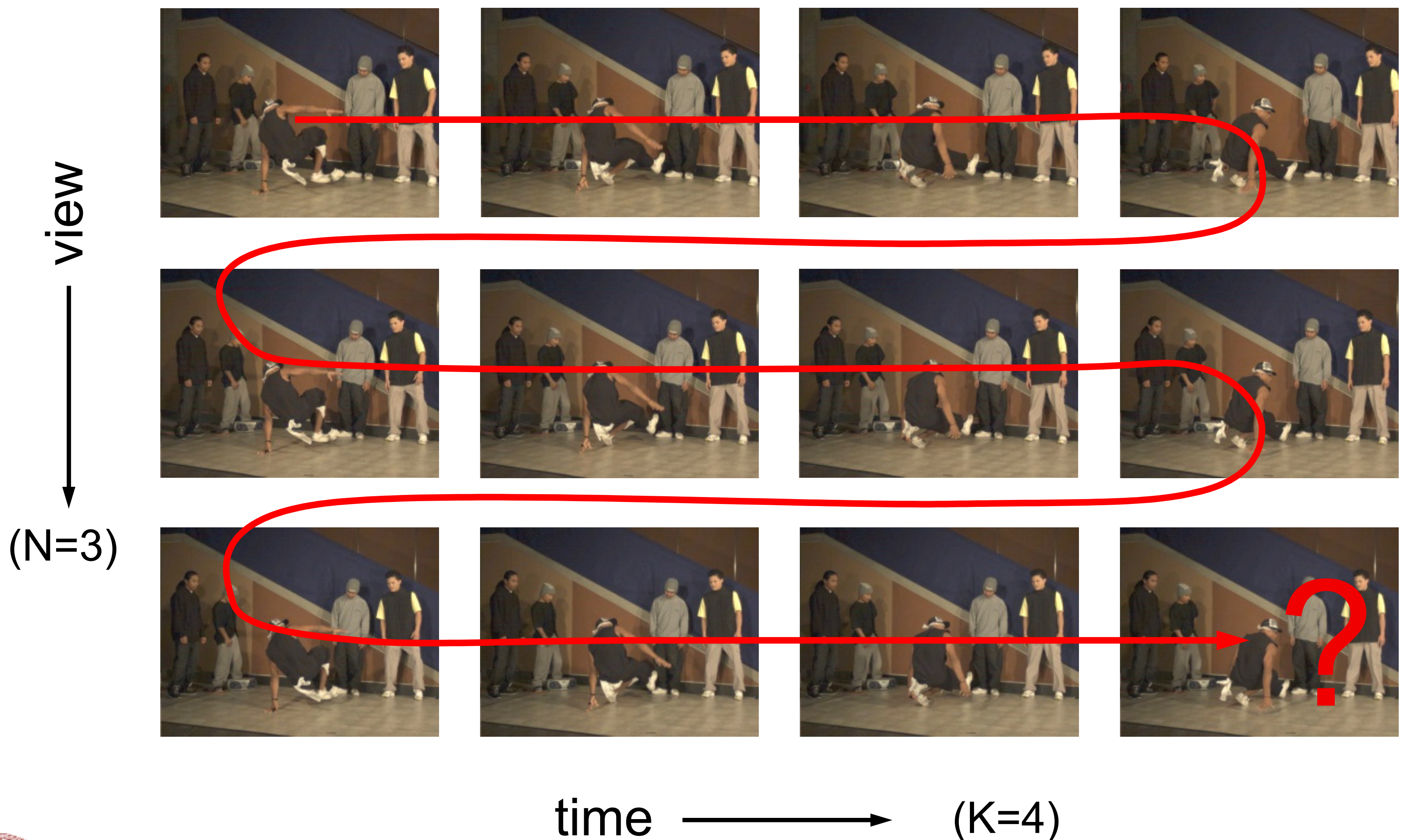
Adaptive Predictive Coding

Widely used in video compression standards like MPEG-1/2/4, H.26x

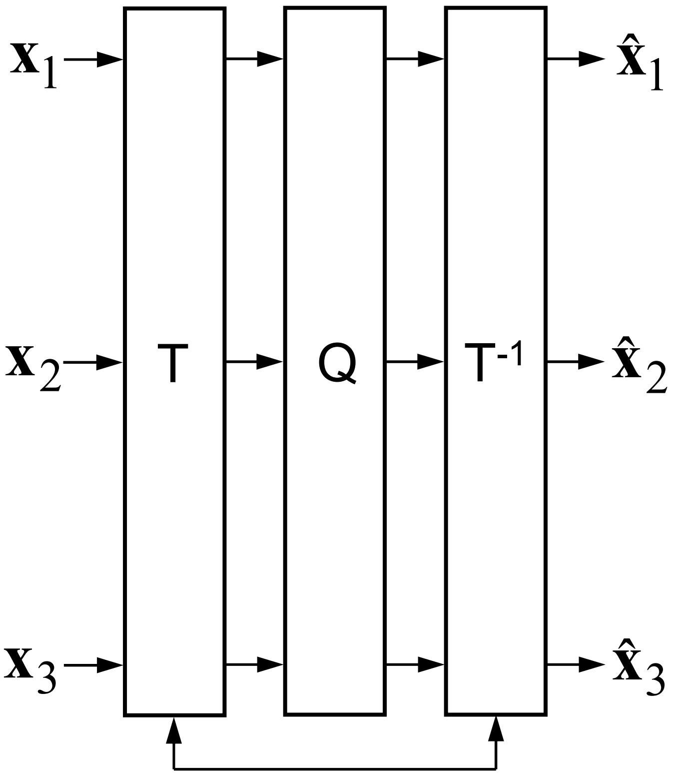


Requires sequential processing of imagery

Sequential Processing – In Which Order?



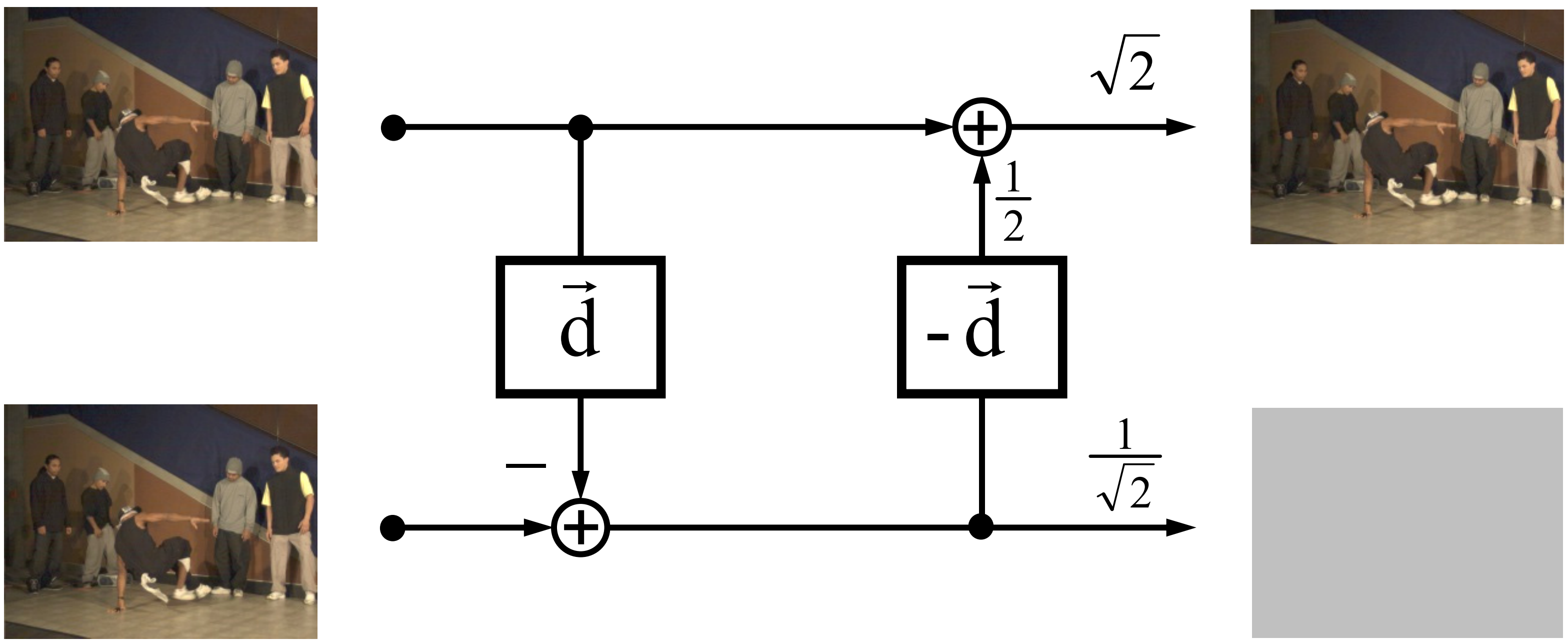
Adaptive Subband Coding



disparity and motion information

State-of-the-Art Subband Coding of Video

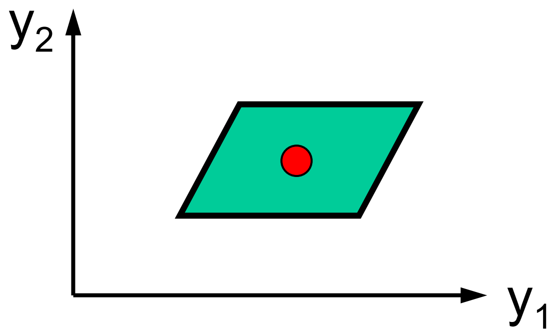
- Motion-compensated lifted wavelets
- **Example:** Motion-compensated lifted Haar wavelet



- Loses property of orthonormality for general multi-connecting motion fields!

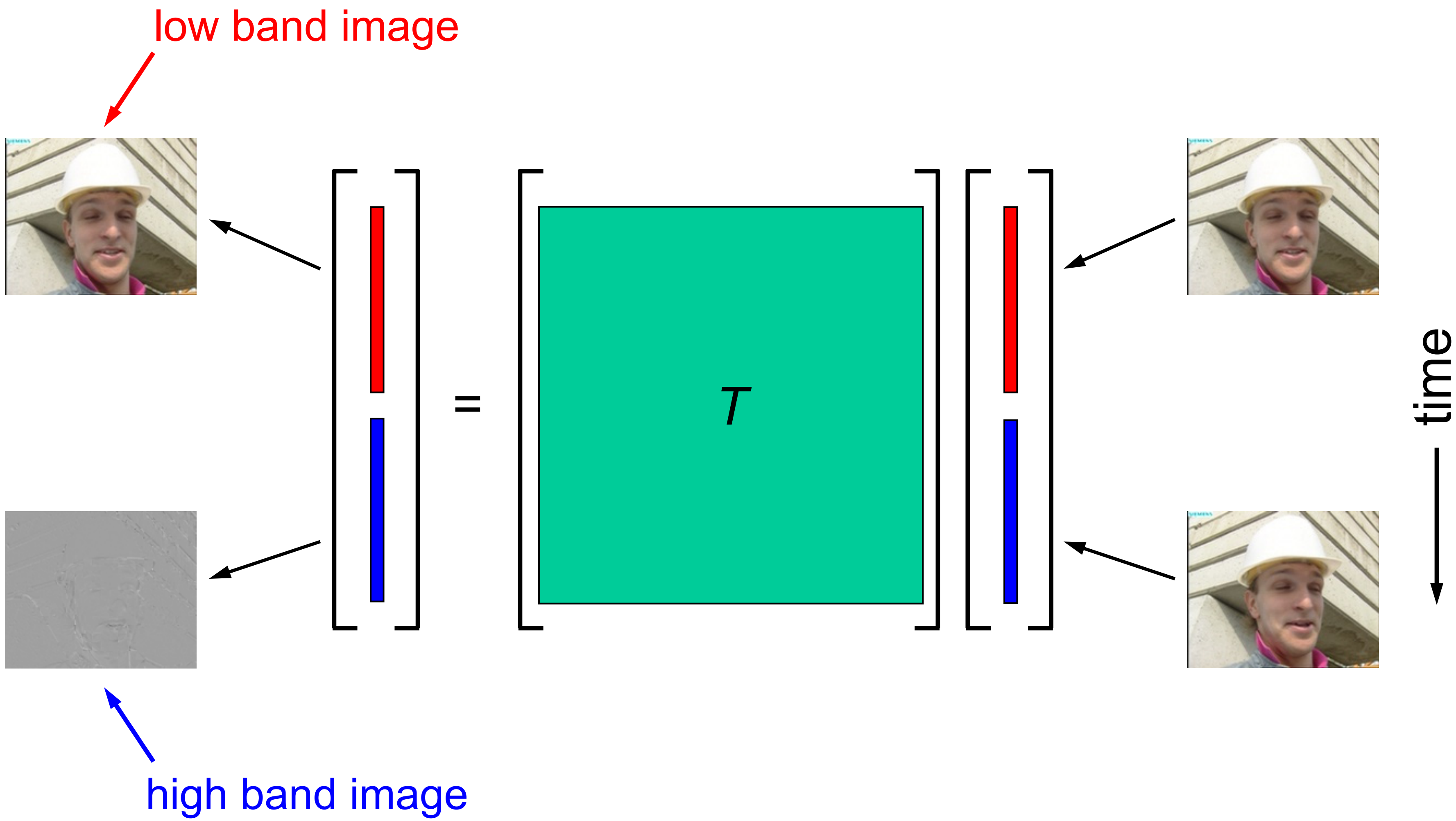
Orthogonal Transforms

- Scalar quantization of transform coefficients
- Orthogonality offers good partition cell shapes



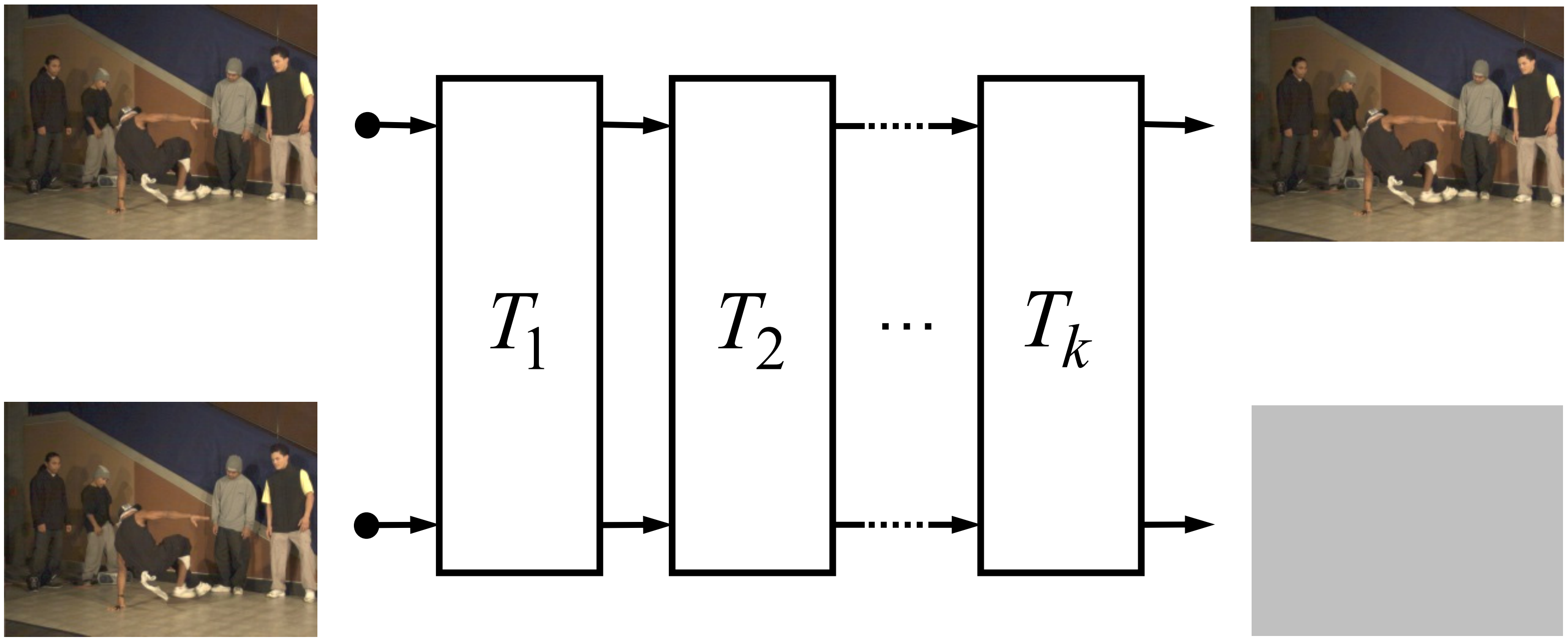
- **Goal:** Adaptive transform that strictly maintains orthonormality

Adaptive Orthogonal Transforms



Adaptive Orthogonal Transforms

- Orthogonal transform *T* for **pairs of input images**:



- Factor *T* into a sequence of *k* **incremental transforms**:

$$T = T_k T_{k-1} \cdots T_\kappa \cdots T_2 T_1$$

- Each incremental transform is orthogonal: $T_\kappa T_\kappa^T = I$

Incremental Transform

$$T_\kappa = \begin{pmatrix} \ddots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \cdots & 1 & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots \\ \cdots & 0 & h_{11} & 0 & \cdots & 0 & h_{12} & 0 & \cdots \\ \cdots & 0 & 0 & 1 & \cdots & 0 & 0 & 0 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ \cdots & 0 & 0 & 0 & \cdots & 1 & 0 & 0 & \cdots \\ \cdots & 0 & h_{21} & 0 & \cdots & 0 & h_{22} & 0 & \cdots \\ \cdots & 0 & 0 & 0 & \cdots & 0 & 0 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

← *i*-th pixel in $\mathbf{x}_1$

← *j*-th pixel in $\mathbf{x}_2$

$$H = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} = \frac{1}{\sqrt{1+a_\kappa^2}} \begin{pmatrix} 1 & a_\kappa \\ -a_\kappa & 1 \end{pmatrix} \quad \text{as} \quad HH^T = I$$

↑ decorrelation factor

Example: Images with Four Pixels

$\mathbf{x}_1^{(1)}$

140	220
100	120

$a_1 = 1$

$\mathbf{x}_2^{(1)}$

140	120
100	100

$\mathbf{x}_1^{(2)}$

$\sqrt{2}$ 140	220
100	120

$a_2 = 1$

$\mathbf{x}_2^{(2)}$

0	120
100	100

$\mathbf{x}_1^{(3)}$

$\sqrt{2}$ 140	220
100	$\sqrt{2}$ 120

$a_3 = 1$

$\mathbf{x}_2^{(3)}$

0	0
100	100

$\mathbf{x}_1^{(4)}$

$\sqrt{2}$ 140	220
$\sqrt{2}$ 100	$\sqrt{2}$ 120

$a_4 = 1/\sqrt{2}$

$\mathbf{x}_2^{(4)}$

0	0
0	100

$\mathbf{x}_1^{(5)}$

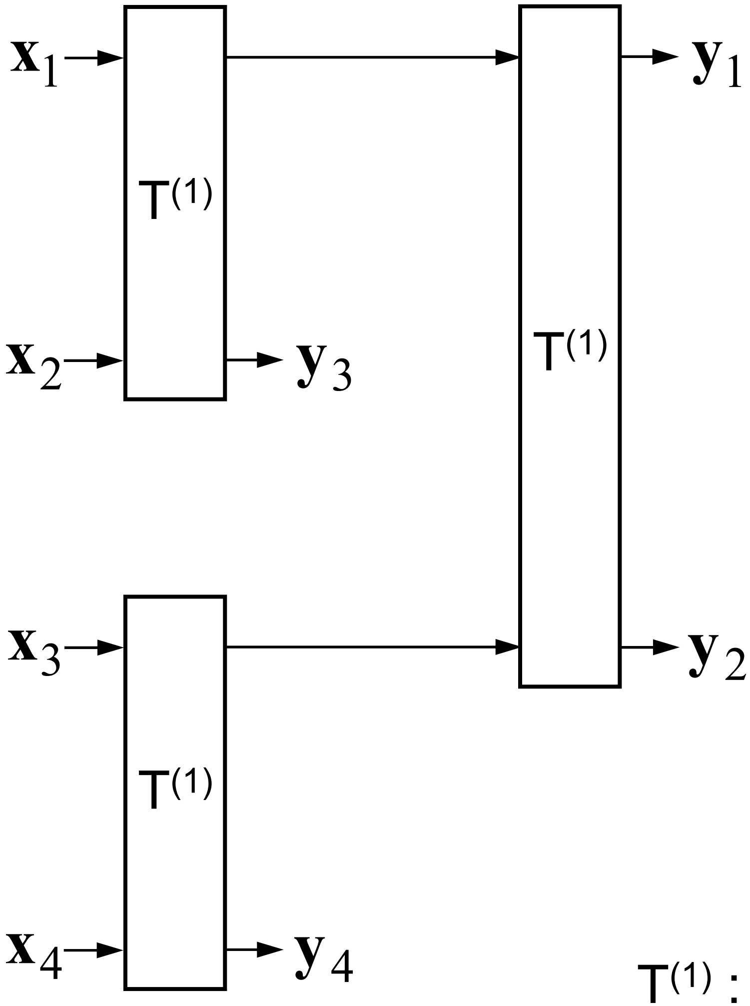
$\sqrt{2}$ 140	220
$\sqrt{3}$ 100	$\sqrt{2}$ 120

$\mathbf{x}_2^{(5)}$

0	0
0	0

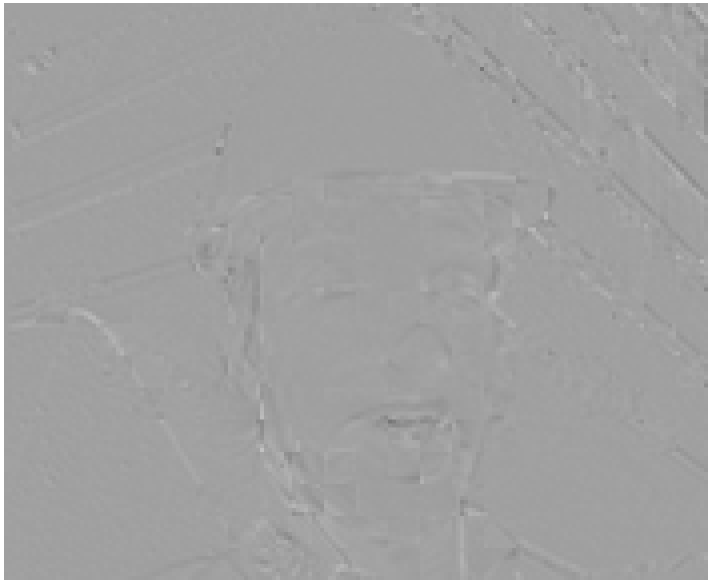
$$\begin{bmatrix} x''_{1,i} \\ x''_{2,j} \end{bmatrix} = \frac{1}{\sqrt{1+a_\kappa^2}} \begin{bmatrix} 1 & a_\kappa \\ -a_\kappa & 1 \end{bmatrix} \begin{bmatrix} x'_{1,i} \\ x'_{2,j} \end{bmatrix}$$

Dyadic Decompositions

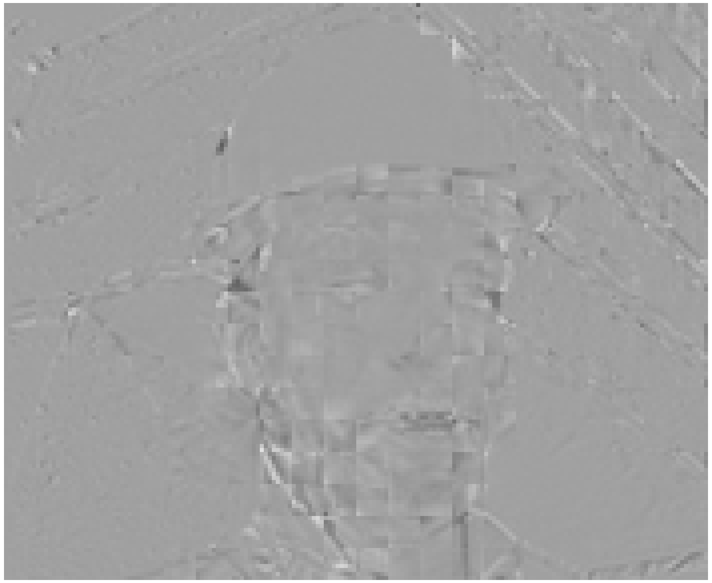


$T^{(1)}$: Orthogonal transform

Example: Dyadic Decomposition



temporal high band
first decomposition level



temporal high band
second decomposition level

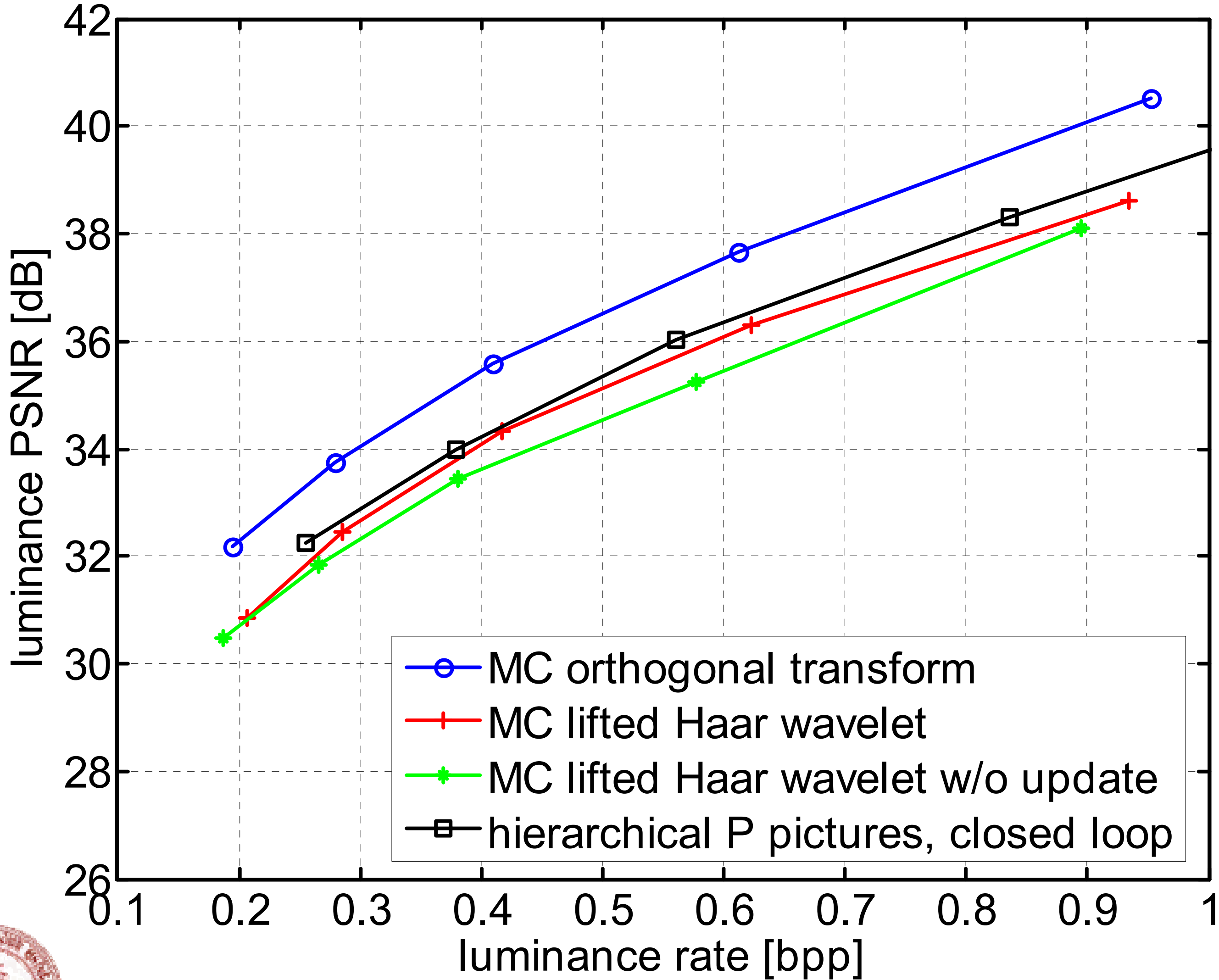
Example: Dyadic Decomposition

temporal low band
second decomposition level

rescaled temporal low band
second decomposition level

$$v = \sqrt{n+1}$$

Example: Dyadic Decomposition



Foreman

QCIF

30 fps

288 frames

GOP size K=16

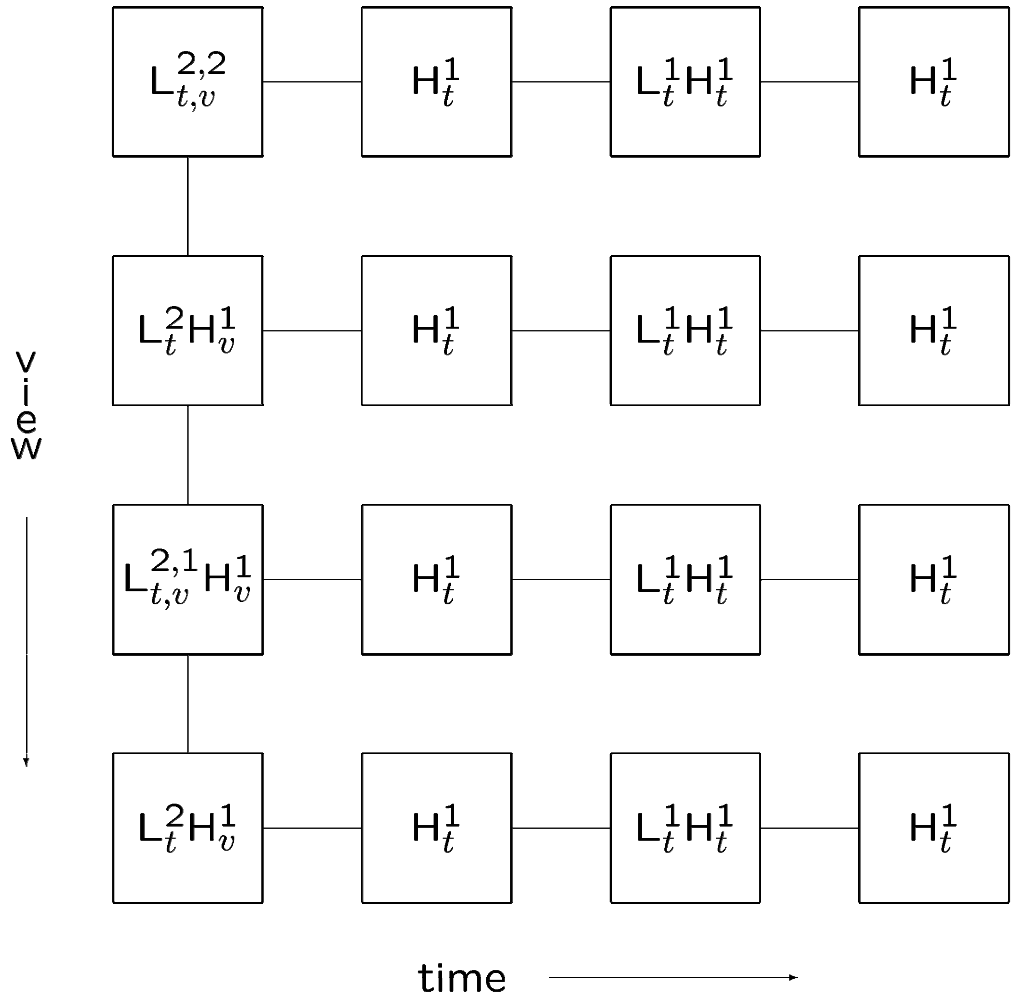
8x8 block motion

Class of Adaptive Orthogonal Transforms

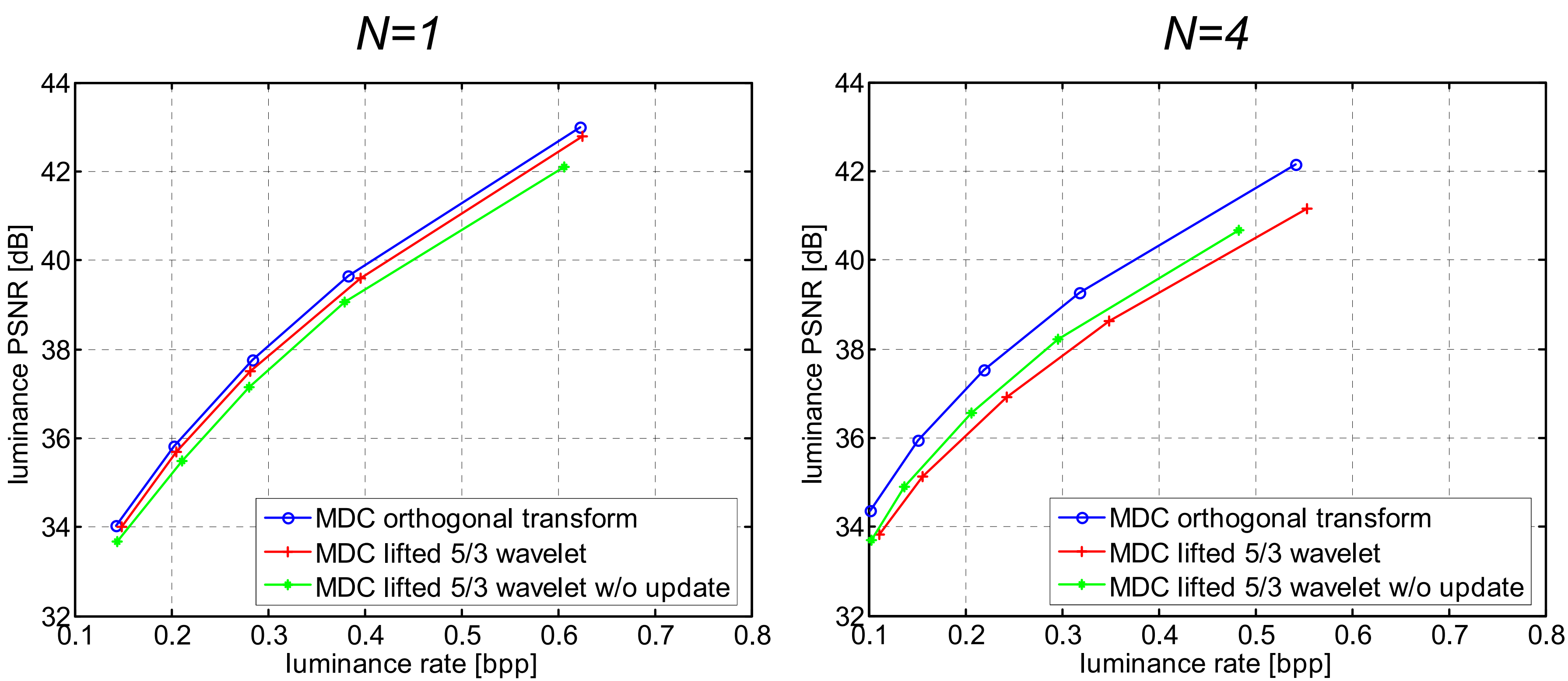
- Unidirectionally Compensated Orthogonal Transform
- Bidirectionally Compensated Orthogonal Transform
- Double Compensated Orthogonal Transform
- P-hypothesis Compensated Orthogonal Transform
- Sub-pel Compensated Orthogonal Transform

Systematic construction based on Euler rotations

Multiview Video Subband Decomposition



Advantage of Strict Orthogonality



Breakdancers

Conclusions

- Multiview video coding
- New class of disparity and motion compensated orthogonal transforms
- No sequential processing necessary
- Strict orthogonality is highly beneficial

Further Reading

http://www.orthogonalvideo.org

Multi-View Video Coding

Demo

DMC lifted 5/3 wavelet   DMC orthogonal transform