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?

view
(N=3)
time
(K=4)
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

\[ T = \begin{bmatrix} \text{low band image} \\ \text{high band image} \end{bmatrix} \begin{bmatrix} \text{time} \end{bmatrix} \]
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

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

- \( i \)-th pixel in \( x_1 \)
- \( j \)-th pixel in \( x_2 \)

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

decorrelation factor
Example: Images with Four Pixels

\[
\begin{bmatrix}
  x''_{1,i} \\
  x''_{2,j}
\end{bmatrix}
= \frac{1}{\sqrt{1 + a_k^2}} \begin{bmatrix}
  1 \\
  -a_k \\
  1
\end{bmatrix}
\begin{bmatrix}
  x'_{1,i} \\
  x'_{2,j}
\end{bmatrix}
\]
Dyadic Decompositions

\[ x_1 \rightarrow T^{(1)} \rightarrow y_1 \]
\[ x_2 \rightarrow y_3 \rightarrow T^{(1)} \rightarrow y_2 \]
\[ x_4 \rightarrow y_4 \rightarrow T^{(1)} \]

\[ T^{(1)} : \text{Orthogonal transform} \]
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

Flierl: Motion-Compensated Orthogonal Transforms for Multiview Video Coding

- MC orthogonal transform
- MC lifted Haar wavelet
- MC lifted Haar wavelet w/o update
- hierarchical P pictures, closed loop

**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

![Graphs showing luminance PSNR vs luminance rate for different transforms](image)

- **Breakingdancers**

  - **N=1**: MDC orthogonal transform, MDC lifted 5/3 wavelet, MDC lifted 5/3 wavelet w/o update
  - **N=4**: MDC orthogonal transform, MDC lifted 5/3 wavelet, MDC lifted 5/3 wavelet w/o update
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