VIDEO ENCODER BASED ON LIFTING TRANSFORMS ON GRAPHS

Eduardo Martínez-Enríquez, Fernando Díaz-de-María[1] and Antonio Ortega[2]

[1] Department of Signal Theory and Communications. Universidad Carlos III, Leganés (Madrid), Spain
[2]Department of Electrical Engineering. University of Southern California, Los Angeles, California, USA

Motivation

- Directional transforms avoid filtering across large discontinuities.
- Smaller high frequency coefficients in those locations.

Goal: Video encoder based on 3-D directional transforms.

- **Related Work:** Lifting in the temporal domain for video coding [Secker and Taubman, 2003, Popescu and Bottreau, 2001].

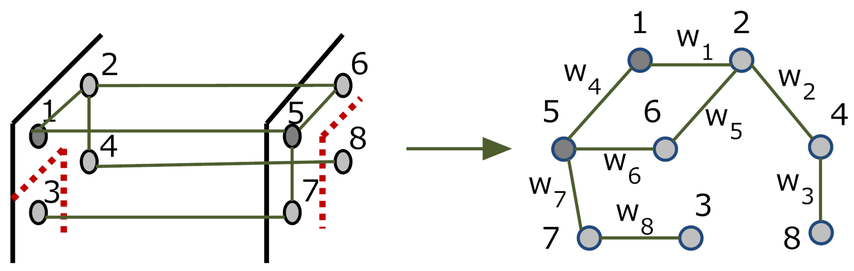
Key Novelties

Introduction to the Transform:

- Describe the video sequence as a **weighted graph** of connected pixels.
- Apply the lifting transform on this graph.

Key Novelties:

- **Graph captures spatio-temporal correlation → spatio-temporal lifting.**
- **Non separable approach**, against common Wavelet-based video coders (t+s).
- Coefficients reordering using graph information.



Lifting Transforms on Graphs

Lifting Transform:

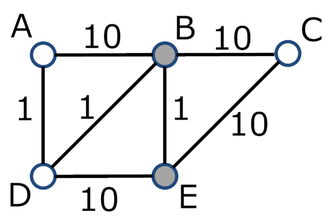
- To perform the transform and ensure its invertibility:
  - Update (U_j)- Prediction (P_j) splitting.
  - Predict (**p**) and update (**u**) filters design.

$$d_{m,j} = s_{m,j-1} + \sum_{k \in U_j} \mathbf{p}_{m,j}(k) s_{k,j-1}$$

$$s_{n,j} = s_{n,j-1} + \sum_{l \in P_j} \mathbf{u}_{n,j}(l) d_{l,j}.$$

Update-Prediction Splitting:

- Invertibility for any disjoint Update-Prediction splitting.
- Criterion we use: **Maximize the total weight of the links between P_j and U_j →Maximum Cut.**



Low Complexity Transform

Problem:

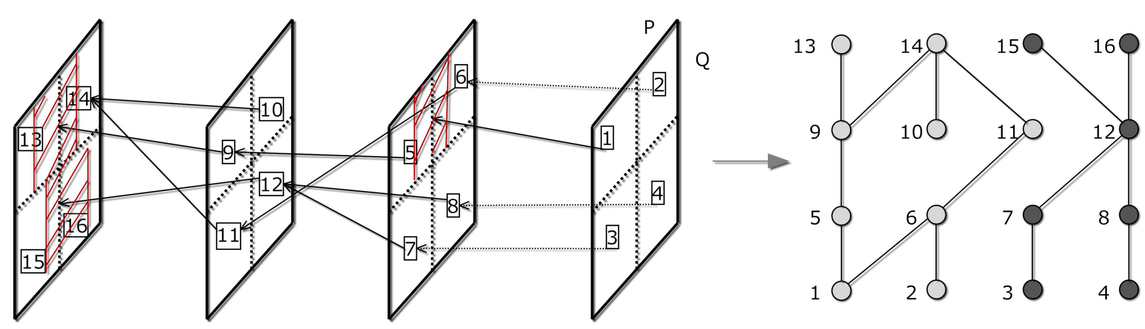
- Encoder complexity increases rapidly with the number of nodes.

Proposed solution:

- Create disjoint subgraphs.
- Mantain the temporal links.

Results:

	Number of Subgraphs	Complexity Reduction
Mobile	82	48
Foreman	14	4
Carphone	1	1



Coefficient Reordering

Goal:

- **Reorder the coefficients generated by our Graph-based transform in an efficient way.**

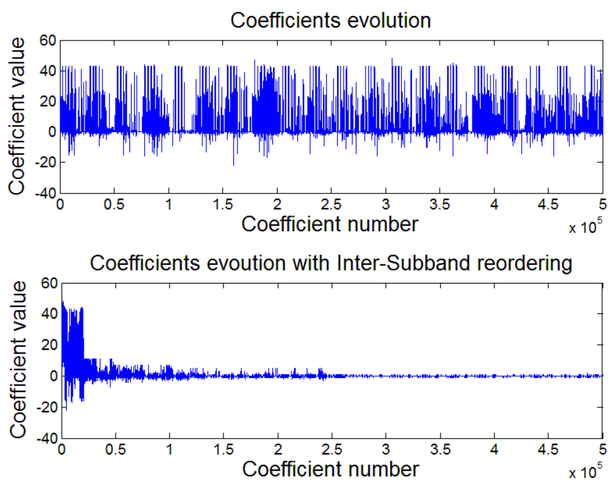
Proposed Solution:

- Reorder the coefficients **using graph information:**
  - Inter-Subband reordering.
  - Intra-Subband reordering.

Inter-Subband Reordering:

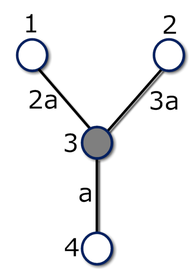
- Group coefficients that belong to **the same subband.**

$$\mathbf{coeffs}_{inter} = \left[\mathbf{s}^{j=N}, \mathbf{d}^{j=N}, \mathbf{d}^{j=N-1}, \ldots, \mathbf{d}^{j=1}\right].$$



Intra-Subband Reordering:

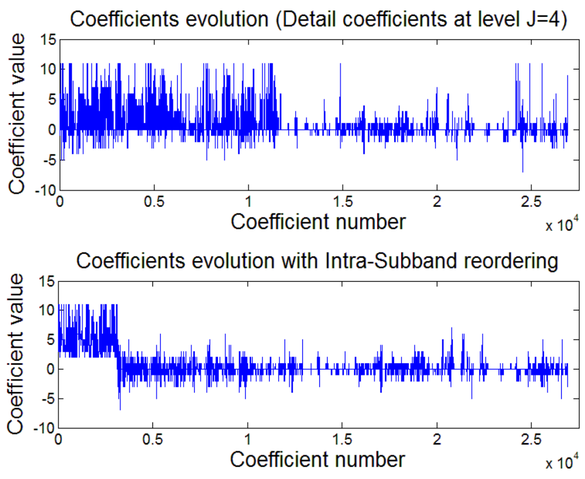
- Reorder the coefficients **in each subband** as a function of the **reliablity of their links.**



$$\mathbf{d}^j = [1, 2, 4]$$

$$\mathbf{r}^j = [2a, 3a, a]$$

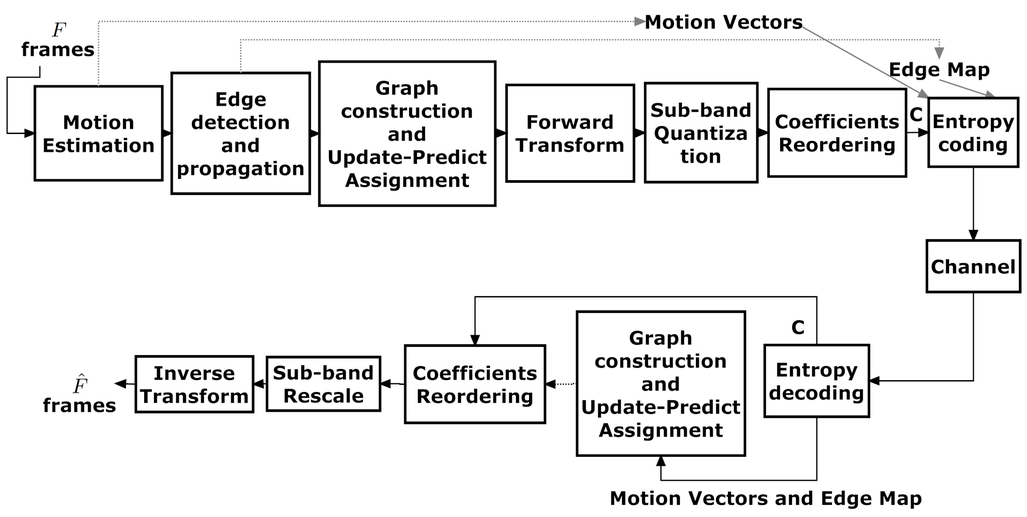
$$\mathbf{d}^j_{intra} = [4, 1, 2].$$



Results:

	Without reordering	Inter reordering	Inter and Intra reordering
Foreman	503 Kbps	404 Kbps	350 Kbps
Carphone	502 Kbps	425 Kpbs	371 Kbps

Encoder and Decoder



Experimental Results

Experimental Setup:

- **Quantization:** Subband dependent quantization.
- **Scanning:** Inter and Intra reordering.
- **Run length** encoding.
- **Arithmetic coding.**
- **5 levels** of the transform.
- **w_t=10; w_s =2.**