Adaptive Compressed Sensing for Depthmap Compression Using Graph-based Transform

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Depthmap Compression

- Depthmap characteristics
  - ▷ Gray-scaled video
  - ▷ Piecewise constant signal
  - ▷ Sharp edges where depth changes
- Precise edge information crucial for view synthesis
  - ▷ The error in edge information
    - → geometry error in interpolated view
    - → significant degradation of the quality [1, 2]
  - ▷ Traditional DCT (H.264/AVC) not efficient for arbitrary edges
    - → Requires edge-adaptive transform; avoid filtering across the edges

Related Work

- Graph-based transform [3]
  - ▷ Represent depth map as a graph
  - ▷ Present edge-adaptive GBT construction
  - ▷ Propose a greedy algorithm to find an optimal transform kernel of GBT
  - ▷ Outperforms H.264/AVC
    - - comparison to this approach will be shown later
- CS-based depthmap compression [4, 5]
  - ▷ Use fixed DCT as sparsifying basis:
    - - inefficient for arbitrary edges
    - - Not adaptive to edges in blocks
  - ▷ Performance was not evaluated with interpolated view quality

Proposed Algorithm

- Propose a design of optimal GBT for CS
  - ▷ Residual depthmap block after intra/inter prediction
  - ▷ Find optimal edgemap (adjacency matrix) with cost function
  - ▷ Generate GBT from edgemap
- GBT construction from edgemap (adjacency matrix)
  - ▷ Given $\mathbf{G(V,E)}$, nodes (pixels) and links (between pixels)
  - ▷ Construct adjacency matrix, $\mathbf{A}$:
    $\mathbf{A(i,j) = 1}$ if no edge between pixels and 0 otherwise
  - ▷ Construct Laplacian matrix, $\mathbf{L}$:

$$\mathbf{L = D - A} = \begin{cases} -1 & \text{if } (i,j) \in E \\ d_i & \text{if } i = j \\ 0 & \text{otherwise} \end{cases}$$

  - ▷ Sparsifying basis $\mathbf{\Psi = [e_1, \ldots, e_N]}$, $\mathbf{e_i}$ is $\mathbf{i^{th}}$ eigenvector of $\mathbf{L}$
- Propose greedy algorithm to find optimal edgemap
  - ▷ Assume 4-neighbor connectivity
    - → 24 possible edges in $\mathbf{4 \times 4}$ block
  - ▷ Define cost:

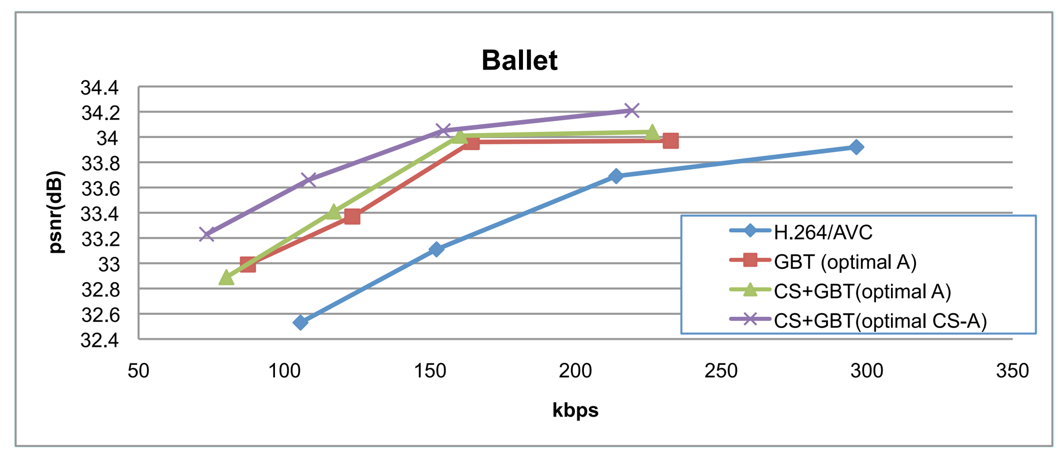
$$\begin{aligned} \mathrm{Cost} &= \mathrm{Cost}_{\mathrm{measurement\_rate}} + \mathbf{k}\mathrm{Cost}_{\mathrm{edge\_rate}} \\ &= \log_2\left(\frac{(\sum_i \mathbf{a_{ij}(x_i - x_j)^2})}{\mathbf{2Q^2}} \mu^2_{\mathbf{avg}}\right) + \mathbf{km} \end{aligned}$$

  - ▷ Initial state: put edges between pixels with different values
    - ▸ Find an edge between smallest pixel difference
    - ▸ Remove the edge if updated cost decreases
    - ▸ Keep doing it until scanning all the edges

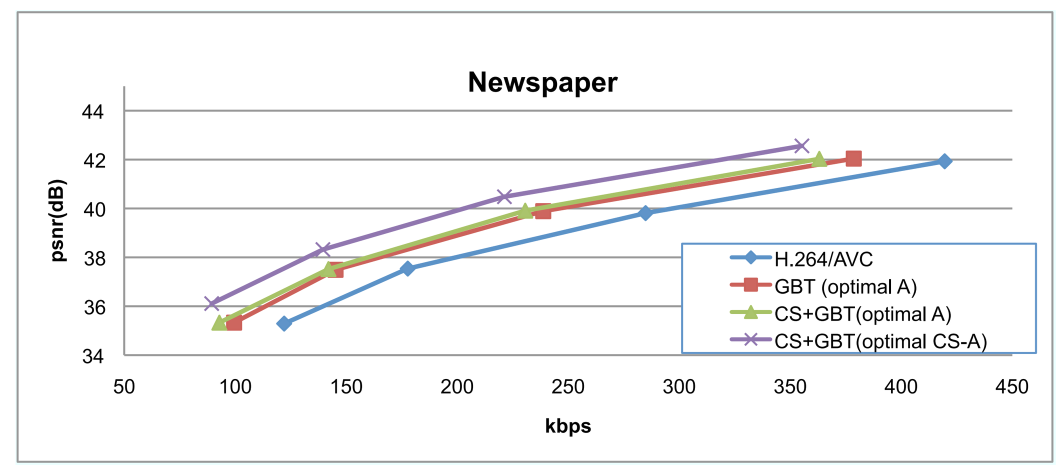
Average Mutual Coherence, μ_{avg}

- $\mu_{\mathbf{avg}}$ can be computed with Hadamard, $\mathbf{\Phi}$, and GBT matrix, $\mathbf{\Psi}$ [6]
  - → complex GBT construction
  - → Increase complexity especially when
  - ▷ depth map block size increases
  - ▷ involved in the greedy algorithm
- Upper bound of $\mu_{\mathbf{upper}}$
  - ▷ $\mu_{\mathbf{upper}} = \sqrt{\frac{\max_{\forall i} N_{G_i}}{N}}$
  - ▷ Depends on the maximum size of group
- Lower bound of $\mu_{\mathbf{lower}}$
  - ▷ $\mu_{\mathbf{lower}} = \max_{\forall k} \sqrt{\frac{\sum_{(l,m)\in E}(\Phi(k,l) - \Phi(k,m))^2}{2|E|}}$
  - ▷ $|\mathbf{E}|$: No. of links = 24 - no. of edges in $\mathbf{4 \times 4}$ blocks
  - ▷ Depends on Hadamard matrix and edge map
- $\mu_{\mathbf{avg}} = \frac{\mu_{\mathbf{lower}} + \mu_{\mathbf{upper}}}{2}$ independent of explicit GBT matrix

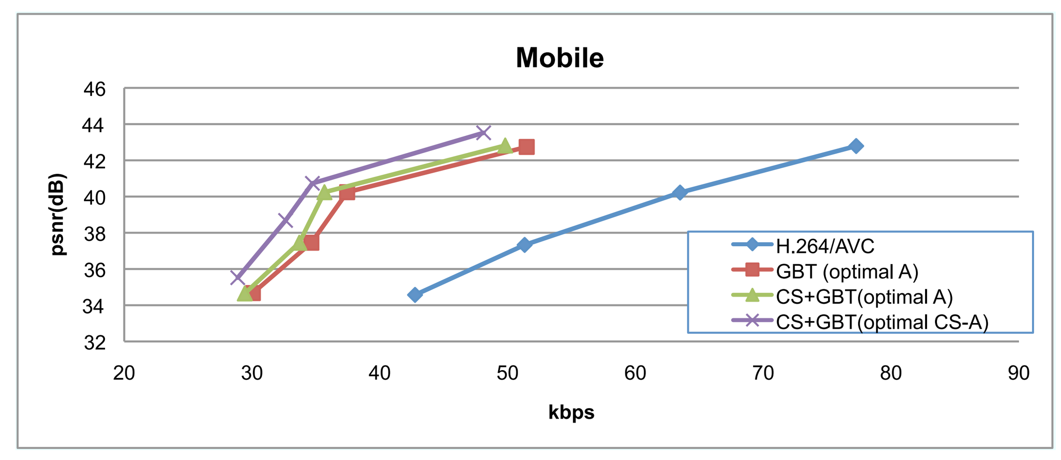
Simulation Result



(a) Ballet

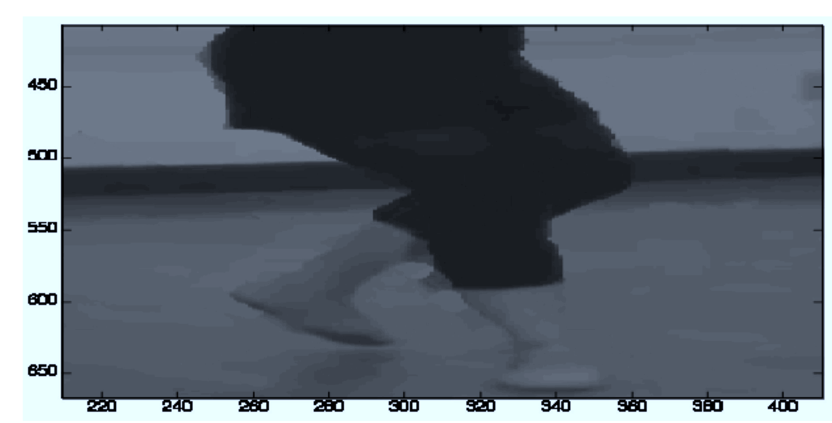


(b) Newspaper

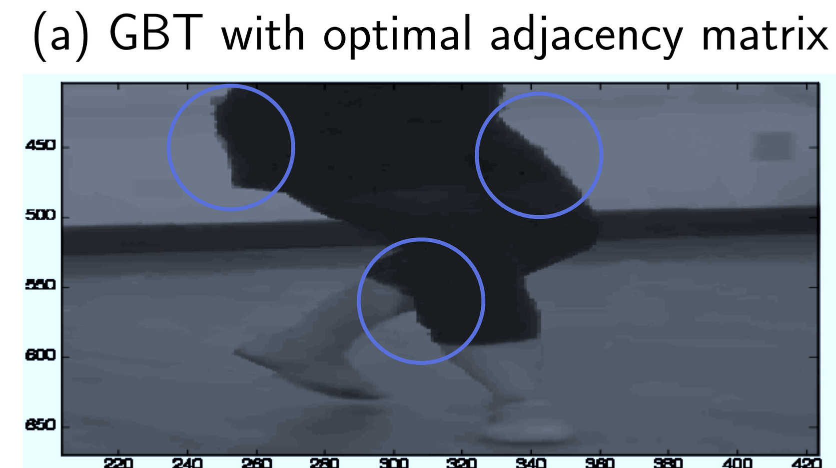


(c) Mobile

Figure: RD curve comparison of i) H.264/AVC ii) GBT and CS-GBT with optimal adjacency matrix [3] iii) CS-GBT with optimal adjacency matrix with averaged mutual coherence for different sequences: (a) Ballet (b) Newspaper (c) Mobile



(a) GBT with optimal adjacency matrix



(b) CS+GBT with optimal adjacency matrix for CS

Figure: Perceptual improvement in Ballet sequence: comparison of (a) GBT and CS-GBT with optimal adjacency matrix [3] (b) CS-GBT with optimal adjacency matrix with averaged mutual coherence

Sequence	BD-PSNR	BD-bitrate
Ballet	0.9	-49.4
Newspaper	1.5	-26.8
Mobile	9.2	-42.8

Table: BD-PSNR/bitrate results of CS-GBT compared to H.264/AVC.

Sequence	BD-PSNR	BD-bitrate
Ballet	0.3	-7.8
Newspaper	0.9	-16.1
Mobile	2.4	-9.7

Table: BD-PSNR/bitrate results of CS-GBT with optimal adjacency matrix for CS compared to CS-GBT with optimal adjacency matrix [3]

Conclusion

- Propose a block-based CS framework applicable to depthmap compression
- Approximate average mutual coherence without constructing GBT
- Find an optimal edgemap (adjacency matrix) for CS
- Proposed approach achieves a significant gain over H.264/AVC

References

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