Contourlet Based Image Compression Using Controlled Modification of Coefficients

Outline

- Introduction
- Contourlet based image compression
- The proposed method
- Implementation and results
- Conclusion
Transform based image compression

- Growing need for compression algorithms
- Type of compression algorithm: Lossy vs Lossless
  - Lossless
    - Prediction and context modeling: JPEGLS, CALIC
  - Lossy
    - JPEG (DCT), JPEG2000 (Wavelet)

The wavelet transform (WT):
- High capability to compress natural images with smooth regions and distinct boundaries
- Not very useful with contours and textured images
New transforms

- Development of the new transforms to overcome the shortcomings of WT
  - Bandelet
  - Curvelet
  - Contourlet (CT)

Some specifications of CT

- A geometric transform which preserve features such as contours and textures.
- Two main parts of the CT:
  - Laplacian pyramid (LP) and directional filter bank (DFB)
- The redundancy ratio of less than 4/3
CT: Contourlet Transform

I \(512 \times 512\) → LP → LF Subband \(256 \times 256\) → LP → LF Subband \(128 \times 128\) → Scale 3 (Approximation) → DFB → Scale 2

Scale 1 (Finest Details)
CT: Contourlet Transform

![Contourlet Transform Diagram](image)
Contourlet based image compression

1. Non-linear approximation (NLA) capabilities of the contourlet transform.
2. Research to avoid the redundancy of the contourlet with the aim of image compression.
3. NLA: Stores $M$ larger coefficients of the transform and discard the rest.
4. The reconstructed image will be an approximation of the original.
5. Most of the details are preserved.
6. Discarded coefficients: The low frequency details and the smooth regions of the image with few details, are affected with the pseudo-Gibbs artifacts.
The proposed contourlet based image compression method

• Modify all coefficients using the constraint

\[ |c - \tilde{c}| \leq d \]

1. Convert coefficients to integers
2. Add/subtract a positive integer to/from coefficient
3. Preserves the fine details of the image
4. Prevents the formation of artifacts in the low frequency details and smooth regions based on the value of d
Alteration with the aim of compression

1. \( d=1 \) can have three different final values
2. About 349526 Coefficients for a 512X512 image (Due to redundancy of CT)
3. About \( 3^{349526} \) different possible combination of coefficients

Decreasing the number of combinations

- Forming a histogram \( H \) for the original integer coefficients
- Changing the values of the coefficients is equivalent to combining the bins of the histogram by partially or totally transferring a bin to an adjacent bin to form a modified histogram \( H' \)
Histogram bin transfer

To obtain a histogram with minimum entropy:
1. Leave a bin intact or totally transfer it.
2. Transfer a bin in one direction.
1. A graph based algorithm to decide what bins need transformation to minimize entropy of the coefficients.
2. Each bin of the histogram = a node in the graph.
3. An arc = a group of coefficients.
4. A path = a histogram of modified coefficients.
5. Arcs labeled with the local entropy that will result from grouping of the bins that the arc indicates.

The diagram illustrates the transformations of coefficients:

- $h'_1 = h_0 + h_1 + h_2$ and $h'_0 = 0, h'_2 = 0$
- $h'_3 = 0, h'_4 = h_3 + h_4$ or $h'_3 = h_3 + h_4, h'_4 = 0$
Input Image

Contourlet Transform

Form Histogram $H$ of Rounded Coefficients

$d$ →

Form Modified Histogram $H'$

$\tilde{C}_{\text{Max}}$ Separation and Mask Generation

$\tilde{C}_{\text{Max}}$ Find The coefficient related to the highest bin

Mask

$\tilde{C}_{\text{Max}}$

$\tilde{C}_{\text{Max}}$

Run Length Encoding

Adaptive Arithmetic Coding

File Forming

Compressed Image

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Proposed method
Mask Generation

\[ \tilde{c}_{\text{Max}} = \arg\max (h'_j), c_{\text{min}} \leq j \leq c_{\text{max}} \]

\[ \tilde{c}_j \]

1. A mask to preserve the location of the coefficients

2. Compress mask using RLE (Run Length Encoding) and Arithmetic coding
Implementation and results

1. Compared with NLA methods based compression using WT and CT.

2. Coefficients were compressed similarly.

3. For the WT and the LP stage of contourlet, we used “9-7” bi-orthogonal filters and 6 decomposition levels.

4. The number of DFB decomposition levels is doubled at each finer scale level and is equal to 5 at the finest scale.
• Better PSNR, for similar bit rates, for **Barbara** and **Goldhill**

• Better PSNR, for similar bit rates, for **Boboon** except for the bit rates between 0.1 to 0.2
Performance Comparison - Visual quality

WT-based NLA (PSNR=24.76)  CT-based NLA (PSNR=25.06)  Ours (PSNR=26.37)

• The Barbara image coded at the bit-rate of 0.25 bpp
Performance Comparison - Visual quality

- WT-based NLA (PSNR= (28.18)
- CT-based NLA (PSNR=27.38)
- Ours (PSNR=28.46).

- The Goldhill image coded at the bit-rate of 0.25 bpp
Performance Comparison - Visual quality

WT-based NLA (PSNR=21.62)  CT-based NLA (PSNR=21.36)  Ours (PSNR=21.95)

- The Baboon image coded at the bit-rate of 0.25 bpp
### Performance Comparison - Non redundant methods

<table>
<thead>
<tr>
<th>Image</th>
<th>Bit Rate (BPP)</th>
<th>WBCT(dB)</th>
<th>Proposed Algorithm (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barbara</strong></td>
<td>0.15</td>
<td>21.41</td>
<td>24.83</td>
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<tr>
<td></td>
<td>0.25</td>
<td>24.73</td>
<td>26.37</td>
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<tr>
<td><strong>Goldhill</strong></td>
<td>0.15</td>
<td>25.22</td>
<td>27.03</td>
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<tr>
<td></td>
<td>0.25</td>
<td>27.04</td>
<td>28.46</td>
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<tr>
<td><strong>Baboon</strong></td>
<td>0.15</td>
<td>19.05</td>
<td>21.09</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>19.88</td>
<td>21.95</td>
</tr>
</tbody>
</table>
Conclusion

1. Our algorithm keeps all of the CT coefficients but alters them to minimize the overall entropy of the compressed coefficients.

2. Better PSNR than WBCT algorithm and preserves image details better than WT or CT based NLA algorithms.
Questions?