Lossless Compression of Brain Volumes

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Motivation

• Magnetic Resonance Imaging produces large 16-bit, 3D image files
• Lossless compression is preferable for diagnosis
• Exploit structure of brain to do better than JPEG, etc.
Goals

• Develop an encoder tailored to MRI brain volumes
• Make use of
  – Brain symmetry
  – Interslice prediction
• Evaluate the encoder against gzip, JPEG-LS+gzip, JPEG-2000+gzip
• Based on paper from UBC [1]

Our Dataset

• Multiple sclerosis study with 26 normals and 26 patients
• 2 typical MRI scans
  – 256x256x124, 16-bit grayscale, MPRAGE
  – 256x256x48, 16-bit grayscale, FLAIR
• Patients usually display asymmetry between left and right halves
  – Less compression?
Examples

MPRAGE

FLAIR

Normal Patient

Block Diagram of System
2-D Wavelet Transform

• Slice by slice
• Lossless integer to integer using lifting scheme
• 4-level decomposition of LL subband
• Daubechies 5/3 wavelets

Symmetry Coding – Global

• Choose horizontal or vertical symmetry based on MSE
• Changes scan order of 16x16 blocks within a subband
• Pre-processing for local symmetry
Symmetry Coding - Local

- Process 16x16 blocks corresponding to global symmetry scan order
- Find:
  - Most similar reference block
  - Symmetry transformation

<table>
<thead>
<tr>
<th>Geometric operation</th>
<th>Sample input block</th>
<th>Output block</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vertical flip</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>2. Horizontal flip</td>
<td>←</td>
<td>→</td>
</tr>
<tr>
<td>3. Diagonal flip</td>
<td>←↑</td>
<td>→↓</td>
</tr>
<tr>
<td>4. Left rotation(90°)</td>
<td>↑←</td>
<td>↓→</td>
</tr>
<tr>
<td>5. Right rotation(90°)</td>
<td>←↑</td>
<td>→↓</td>
</tr>
<tr>
<td>6. Left rotation(90°) + vertical flip</td>
<td>↑←↑</td>
<td>↓→→</td>
</tr>
<tr>
<td>7. Right rotation(90°) + vertical flip</td>
<td>←↑↑</td>
<td>→→↓</td>
</tr>
<tr>
<td>8. No operation</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

- Encode types of symmetry and reference block numbers
- Send residuals to interslice DPCM
**Interslice DPCM**

- In a symmetry residual subband, 16x16x16 blocks
- 5 prediction modes
  - No shift
  - Left, right, up, down shifts
- Choose prediction with smallest MSE
- Send residuals from this stage to EBCOT

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**EBCOT**

- Bit-plane coding with contexts
  - Significance coding (10)
  - Sign coding (5)
  - Magnitude Refinement (3)
- Adaptive arithmetic coding
- Did not implement optimized truncation
VCL Coder

- Exponential-Golomb coding, order 0
  - Codes non-negative integers: our prediction parameters
  - Universal code: within a factor of the optimal code for a monotonic PMF

Results - Normal MPRAGE

![Distribution of Symmetry Modes](image)

![Distribution of Global Symmetry](image)
Results - Normal MPRAGE

Distribution of DPCM Modes

DPCM Mode

Results - Normal MPRAGE

Compression Ratio for MPRAGE Normals

Coder
Results - Patient MPRAGE

Results - Normal FLAIR
Results - Patient FLAIR

![Compression Ratio for FLAIR Patients](image)

Attempted Improvements

- Image vs. transform domain
- Mode choice based on smallest residual entropy vs. MSE
- Entropy coding
  - New sign coding contexts (9 up from 5)
  - Resetting context probabilities at different granularities
Future Work

- Decoder
- More global symmetry modes
- Lossy compression using optimized truncation

References