Lossy Compression of Stochastic Halftones with JBIG2

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Introduction

- Digital halftoning
  - Continuous tone to bi-level
- Ordered dithered halftones
  - Periodic mask of thresholds
- Stochastic halftones
  - Shape quantization noise into high frequencies
Joint Bi-Level Experts Group

- **JBIG2 Standard**
  - Document printing, faxing, scanning, storage
  - Lossy and lossless coding
  - Models for text, halftone, and generic regions
- **Lossy JBIG2 Compression of Halftones**
  - Preserve local average gray level not halftone
  - Spatially periodic descreening
  - High compression of ordered dither halftones
Motivation

- Improve JBIG2 performance on stochastic halftones

Existing JBIG2
6.1 : 1

Proposed Method
6.6 : 1
Lossy Compression of Halftones

Generate \((M^2+1)\) patterns of size \(M \times M\) from a clustered dot threshold mask

Halftone

Construct Pattern Dictionary

Compute Indices into Dictionary

Lossless Encoder

Count black dots in each \(M \times M\) block of input
Range of indices: 0 ... \(M^2+1\)

JBIG2 bitstream
Proposed Method

- 3 x 3 lowpass
- zeros at Nyquist
- removes noise artifacts
- power-of-two coefficients

- modified multilevel
  Floyd Steinberg
  error diffusion
- optionally reduce N
- L sharpening factor
- one multiply/add

Half tone

Prefilter → Decimator → Quantizer → Lossless Encoder → JBIG2 bit stream

Symbol Dictionary

- N patterns
- size M x M
- may be angled
- clustered dot

gray levels

2 17 16 M^2 + 1 N

- M x M lowpass averaging filter
- downsample by M x M
- Model degradation as linear filter plus noise
- Decouple and quantify linear and additive effects
- Contrast sensitivity function (CSF) $C(\omega_1, \omega_2)$
  - Linear shift-invariant model of human visual system
  - Weighting of distortion measures in frequency domain
Quality Metrics

- Estimate linear model by Wiener filter
- Weighted Signal to Noise Ratio (WSNR)
  - Weight noise $D(u, v)$ by CSF $C(u, v)$

$$\text{WSNR} = 10 \log_{10} \left( \frac{\sum_u \sum_v |X(u, v)C(u, v)|^2}{\sum_u \sum_v |D(u, v)C(u, v)|^2} \right)$$

- Linear Distortion Measure
  - Weight distortion by input spectrum $X(u, v)$ and CSF $C(u, v)$

$$\text{LDM} = \frac{\sum_u \sum_v |1 - H(u, v)||X(u, v)C(u, v)|}{\sum_u \sum_v |X(u, v)C(u, v)|}$$
Results

512 x 512 Floyd Steinberg halftone of barbara image

High Quality
Ratio  6.6 : 1
WSNR  18.7 dB
LDM   0.116

High Compression
Ratio  9.9 : 1
WSNR  14.0 dB
LDM   0.158
## Results

Results for $512 \times 512$ Floyd Steinberg halftone

<table>
<thead>
<tr>
<th>Prefilter</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>$\theta$</th>
<th>LDM</th>
<th>WSNR</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>0.0</td>
<td>4</td>
<td>17</td>
<td>0°</td>
<td>0.163</td>
<td>15.4 dB</td>
<td>6.1</td>
</tr>
<tr>
<td>Y</td>
<td>0.0</td>
<td>4</td>
<td>17</td>
<td>0°</td>
<td>0.181</td>
<td>16.5 dB</td>
<td>7.5</td>
</tr>
<tr>
<td>Y</td>
<td>0.5</td>
<td>4</td>
<td>17</td>
<td>0°</td>
<td>0.091</td>
<td>16.0 dB</td>
<td>6.4</td>
</tr>
<tr>
<td>Y</td>
<td>1.5</td>
<td>4</td>
<td>17</td>
<td>0°</td>
<td>0.292</td>
<td>14.8 dB</td>
<td>5.2</td>
</tr>
<tr>
<td>Y</td>
<td>0.5</td>
<td>6</td>
<td>19</td>
<td>45°</td>
<td>0.116</td>
<td>18.7 dB</td>
<td>6.6</td>
</tr>
<tr>
<td>Y</td>
<td>0.5</td>
<td>8</td>
<td>33</td>
<td>45°</td>
<td>0.155</td>
<td>15.7 dB</td>
<td>8.2</td>
</tr>
<tr>
<td>Y</td>
<td>0.5</td>
<td>8</td>
<td>16</td>
<td>45°</td>
<td>0.158</td>
<td>14.0 dB</td>
<td>9.9</td>
</tr>
</tbody>
</table>
Rate Distortion Curve - LDM

Compressed Image Size (bytes)

Sharpness Parameter
- ○ $L = 0.0$
- × $L = 1.0$
Conclusions

• JBIG2 encoding of stochastic halftones
  – Reduce noise and artifacts
  – Achieve higher compression ratios
  – Require low computational complexity

• Rate distortion tradeoffs of free parameters
  – Quality metrics consistent with visual quality