Lossy Compression of Stochastic Halftones with JBIG2

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Introduction

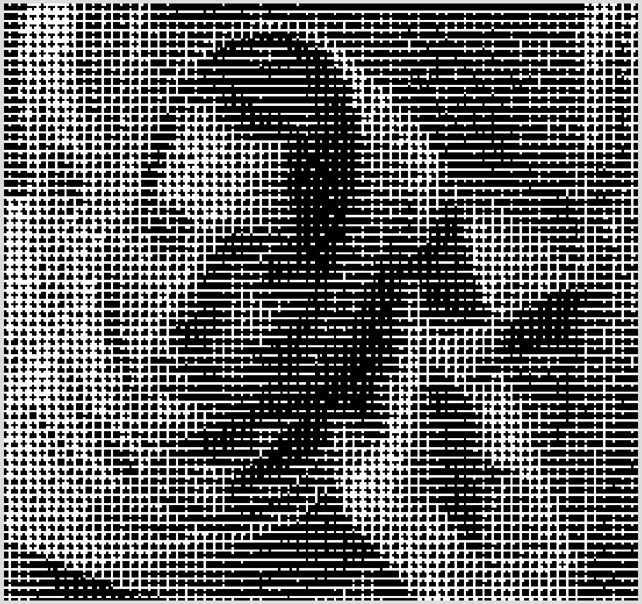
- Digital halftoning
  - Continuous tone to bi-level
- Ordered dithered halftones
  - Periodic mask of thresholds
- Stochastic halftones
  - Shape quantization noise into high frequencies

Joint Bi-Level Experts Group

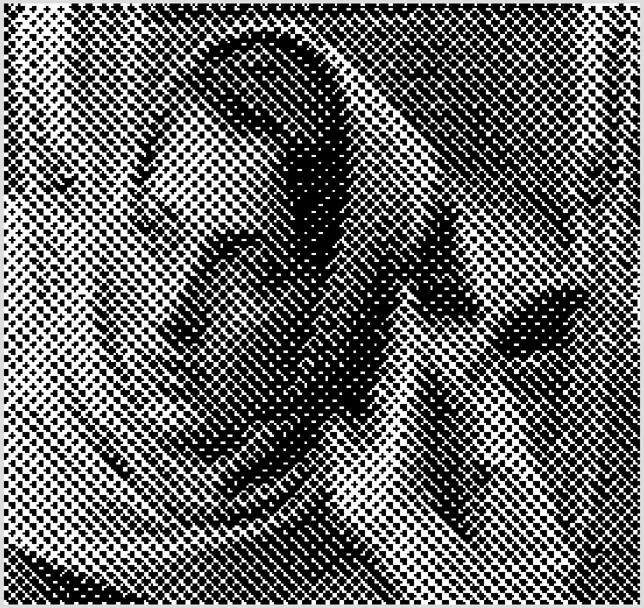
- JBIG2 Standard
  - Document printing, faxing, scanning, storage
  - Lossy and lossless coding
  - Models for text, halftone, and generic regions
- Lossy JBIG2 Compression of Halftones
  - Preserve local average gray level not halftone
  - Spatially periodic descreening
  - High compression of ordered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

Motivation

- Improve JBIG2 performance on stochastic halftones

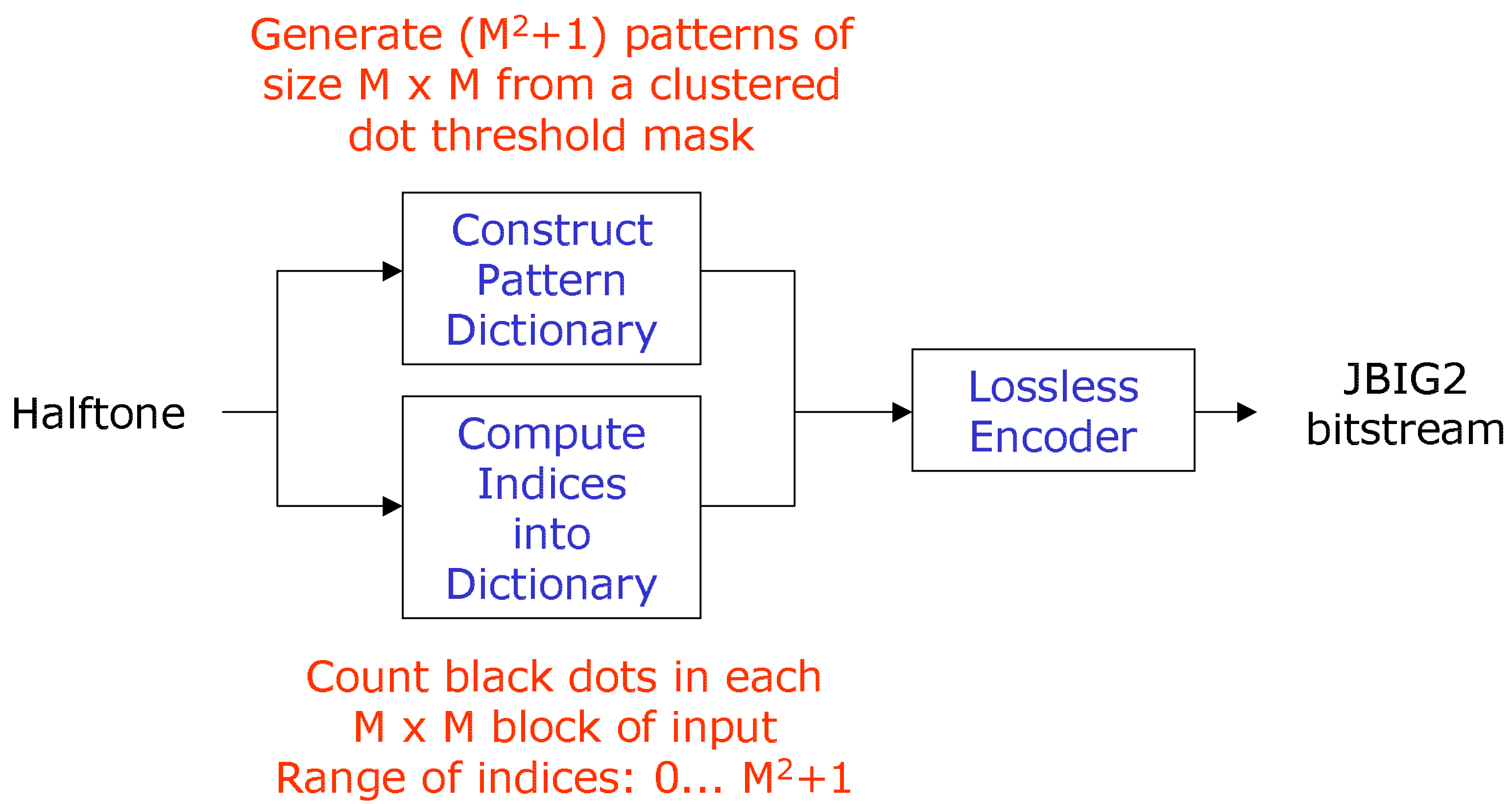


Existing JBIG2
6.1 : 1



Proposed Method
6.6 : 1

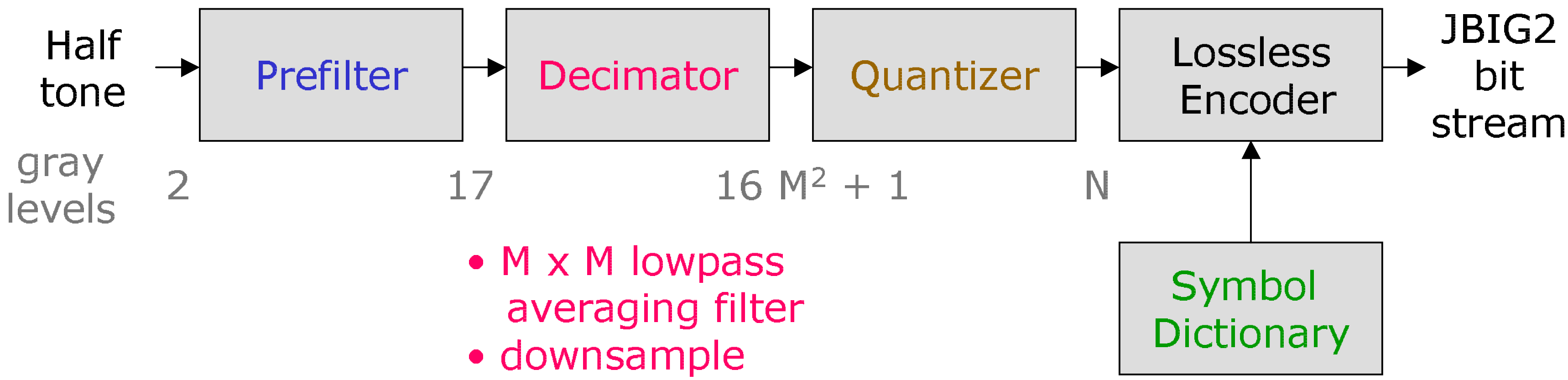
Lossy Compression of Halftones



Proposed Method

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

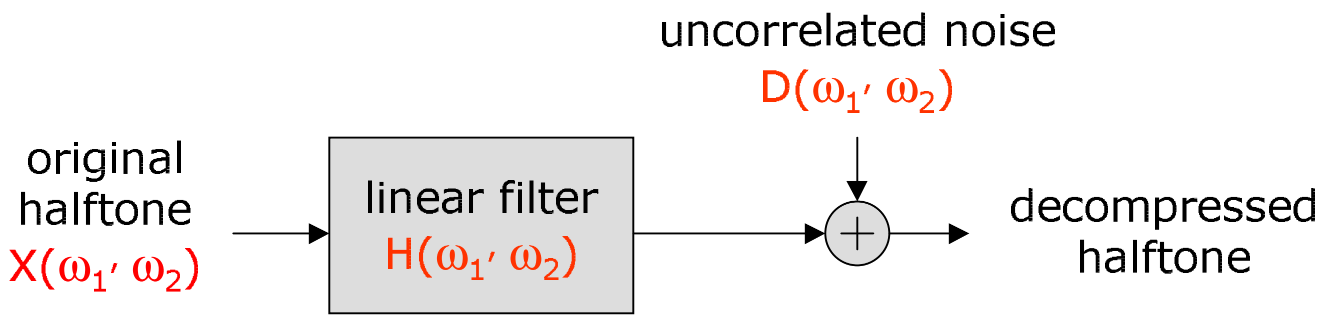
- modified multilevel Floyd Steinberg error diffusion
- optionally reduce N
- L sharpening factor
- one multiply/add



- M x M lowpass averaging filter
- downsample by M x M

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

Quality Metrics



- 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

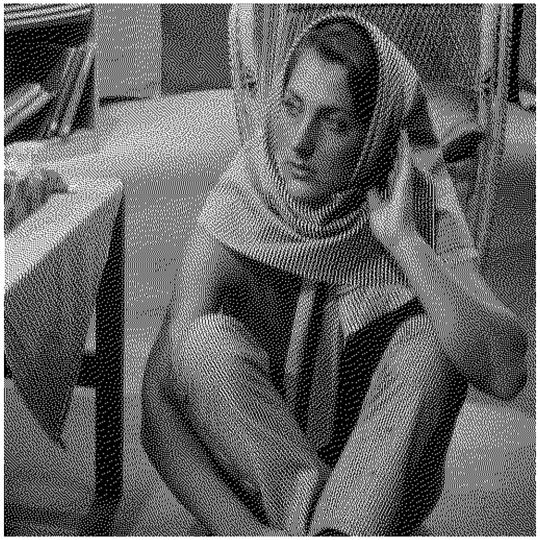
- Estimate linear model by Wiener filter
- Weighted Signal to Noise Ratio (WSNR)
  - Weight noise D(u , v) by CSF C(u , v)

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

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

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

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

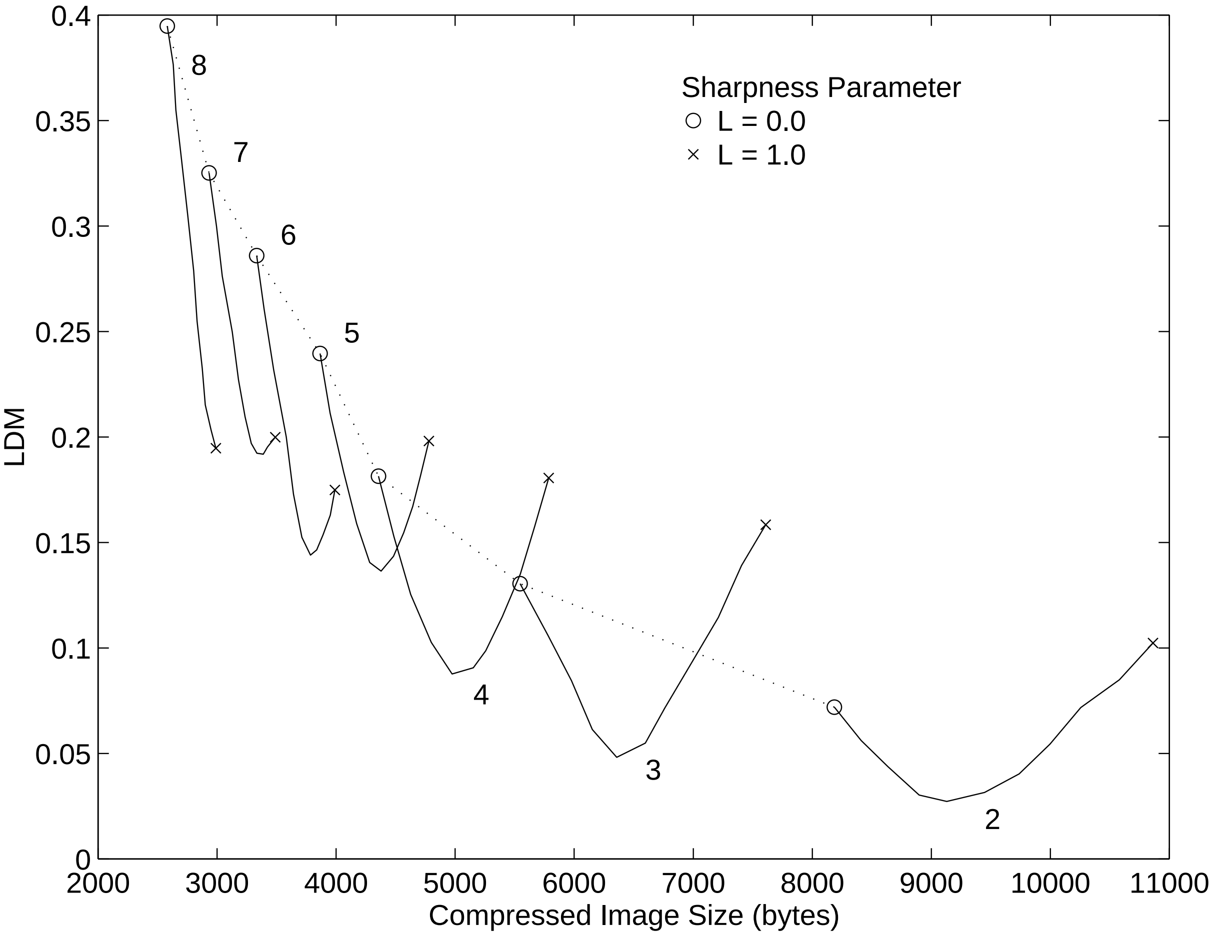
Ratio	9.9 : 1
WSNR	14.0 dB
LDM	0.158

Results

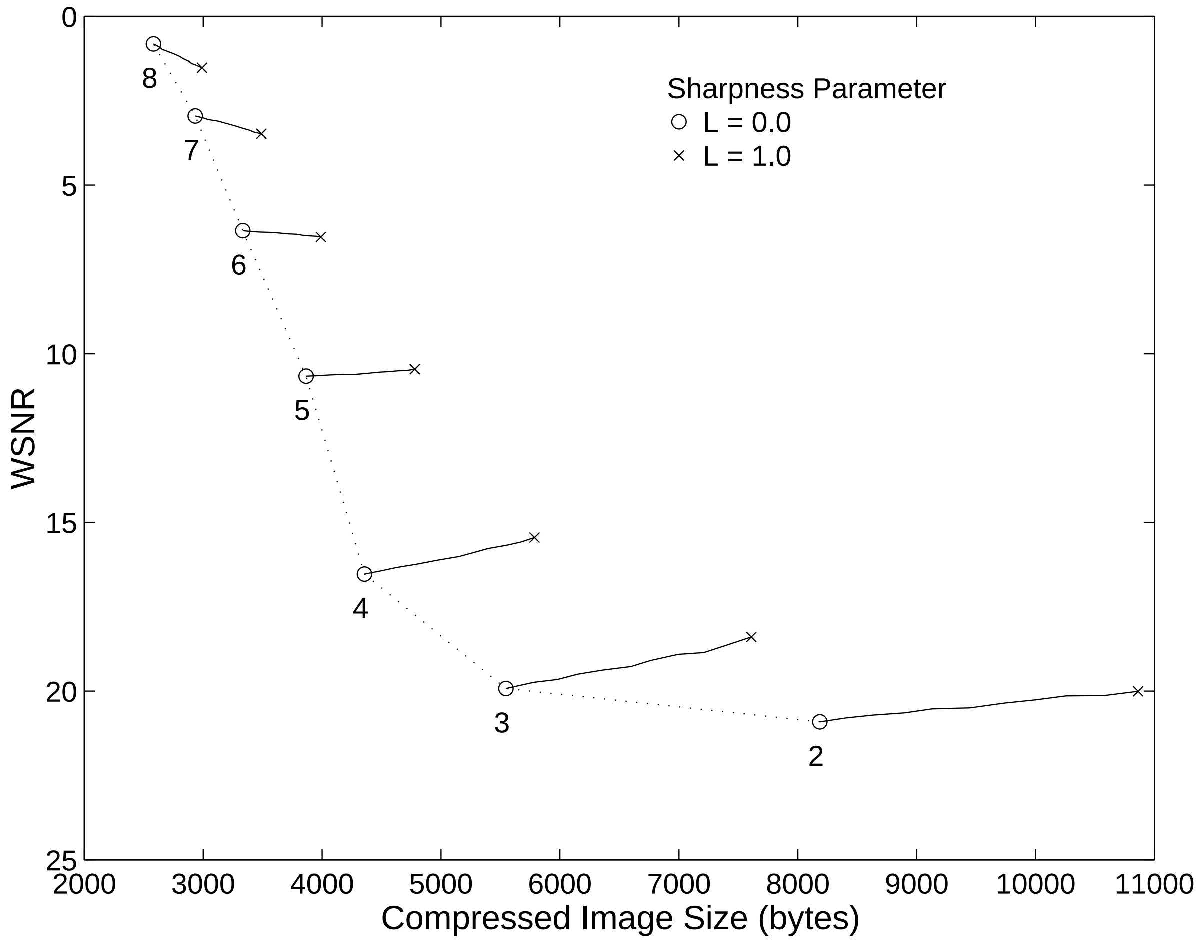
Results for 512 × 512 Floyd Steinberg halftone

Prefilter	L	M	N	θ	LDM	WSNR	Ratio
X	0.0	4	17	0^o	0.163	15.4 dB	6.1
Y	0.0	4	17	0^o	0.181	16.5 dB	7.5
Y	0.5	4	17	0^o	0.091	16.0 dB	6.4
Y	1.5	4	17	0^o	0.292	14.8 dB	5.2
Y	0.5	6	19	45^o	0.116	18.7 dB	6.6
Y	0.5	8	33	45^o	0.155	15.7 dB	8.2
Y	0.5	8	16	45^o	0.158	14.0 dB	9.9

Rate Distortion Curve - LDM



Rate Distortion Curve - WSNR



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