Watermarking for Halftone Images

▲ 1. Digitally forged image on the February 1994 cover of Scientific American. Courtesy of Jack Harris, who manipulated the image.

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Outline

- Overview
- Halftone
  - Error Diffusion
  - Ordered Dither
- Watermarking by DHST
- Watermarking by Bit Interleaving

Overview (1/5)

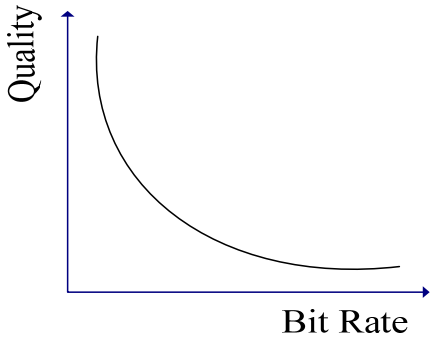
- What is watermark?
- Category of watermarking
  - Copyright protect
  - Image authentication

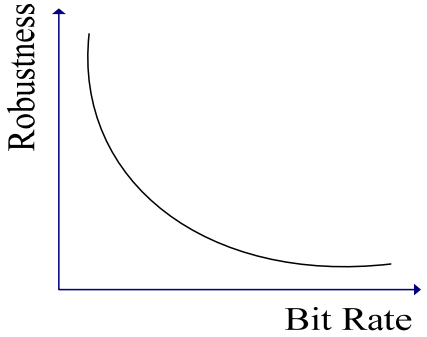
Overview (2/5)

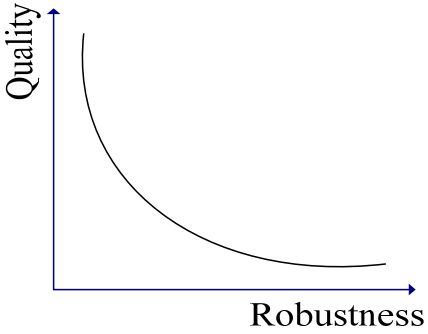
- Characteristic of watermarking
  - Robust or Fragile
  - Imperceptible (transparency)
  - Security
  - Blind

Overview (3/5)

- Trade-off







Overview (4/5)

- Evaluation of image quality
  - PSNR(peak signal noise ratio)

$$PSNR = 10 \cdot \log_{10} \frac{255 \times 255}{MSE}$$

$$MSE = \frac{1}{HW} \sum_{x=0}^{H-1} \sum_{y=0}^{W-1} [f(x,y) - g(x,y)]^2$$

- Verify watermark
  - NC(Normalized correlation)

$$NC = \frac{\sum_i \sum_j w(i,j) w'(i,j)}{N_w}$$

Overview (5/5)

- Detection Theory
  - Bayes decision rule $d^* = d_i; i.e., X \sim \omega_i$ if

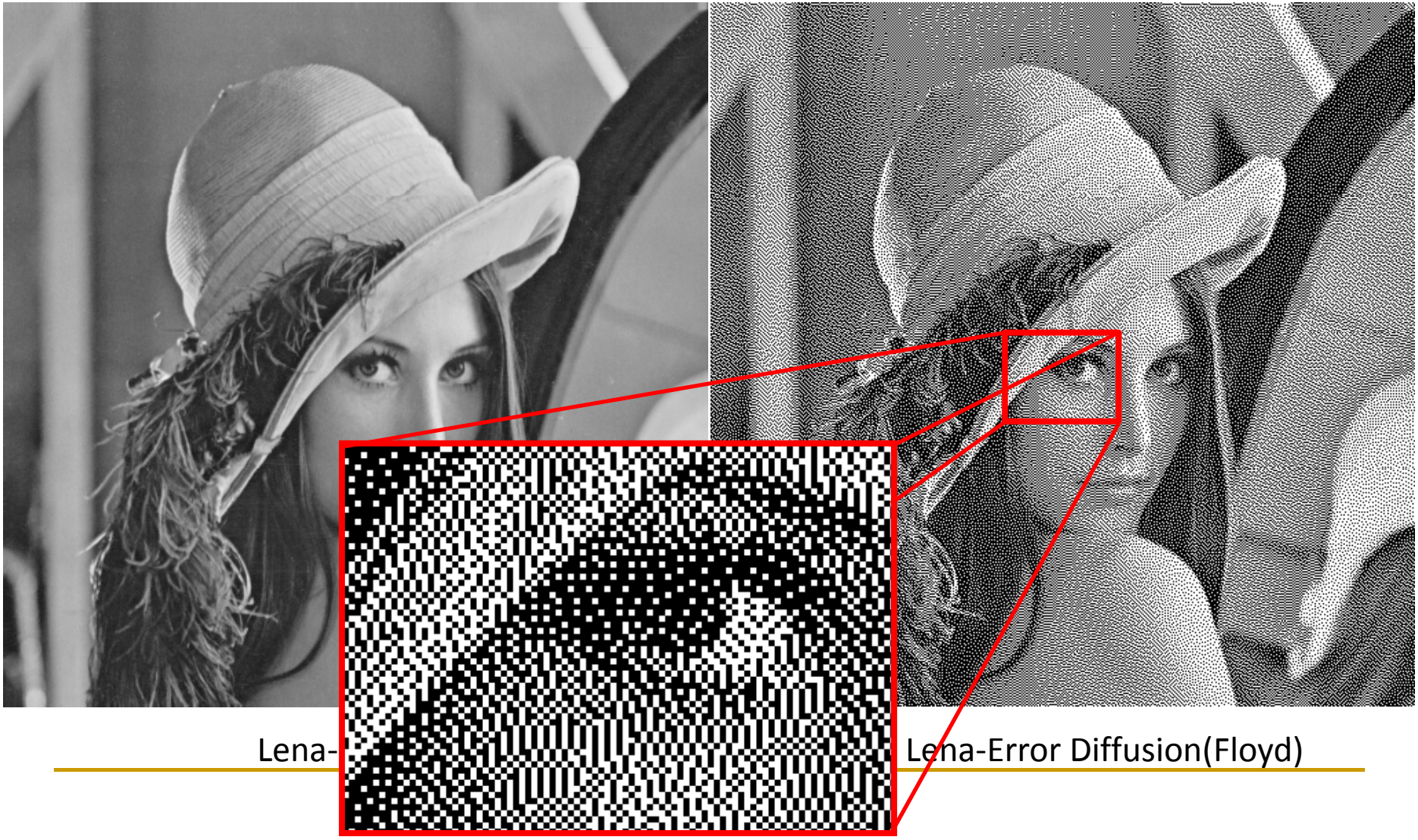
$P(\omega_i)p(X/\omega_i) \geq P(\omega_j)p(X/\omega_j)$ for all j = 1,⋯,m

  - Likelihood ratio

$$\lambda = \frac{p(X/\omega_i)}{p(X/\omega_j)}; \lambda \geq \frac{P(\omega_i)}{P(\omega_j)} \leftarrow priori \quad probabilit\ y$$

  - Maximum likelihood decision with a equal priori probability .

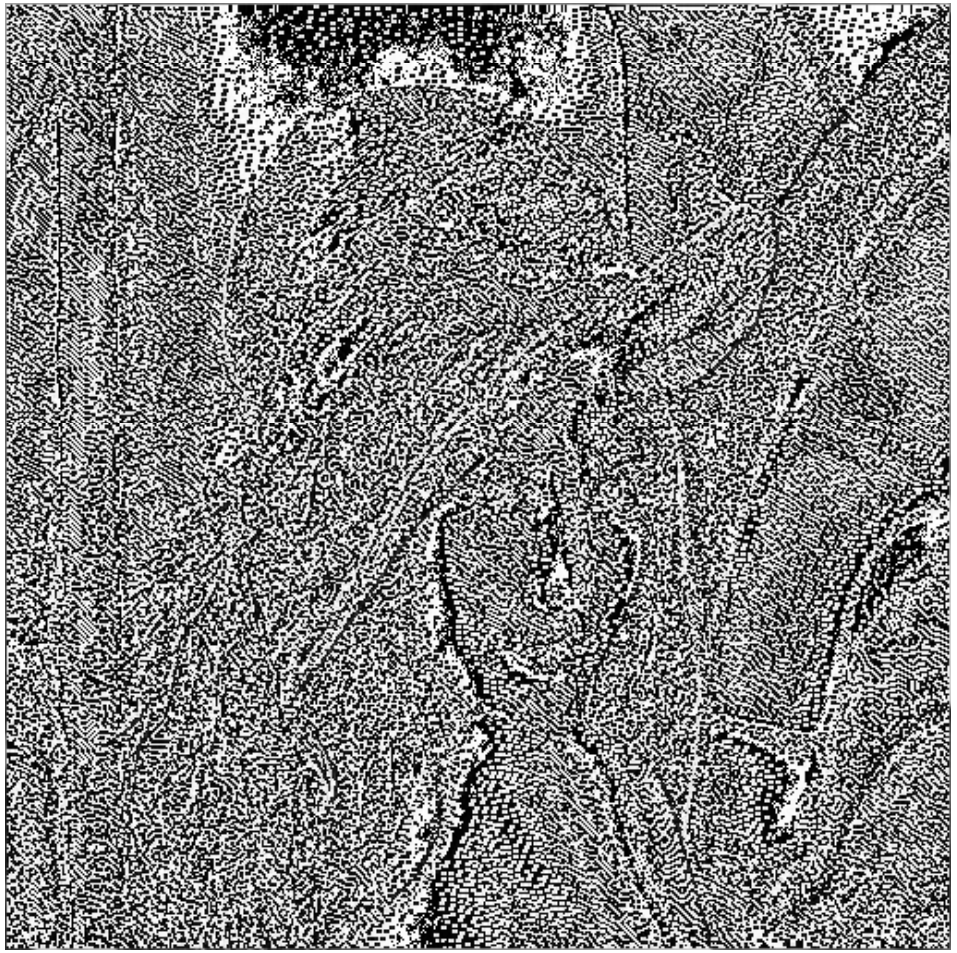
Halftone-Error Diffusion



Lena-

Lena-Error Diffusion(Floyd)

Lena-Error Diffusion(LowPass Filter)



Lena-(256Gray-LowPass Filter)

Halftone-Ordered Dither

Let d(i, j) be the dither matrix of size MxN, then

x(i, j) = 1 if f(i, j) >= d(i mod M, j mod N)

0 if f(i, j) < d(i mod M, j mod N)

containing m=MxN integers, all the integers are from 1 to m.

clustered-dot dither matrix, (i, i + 1) occupy adjacent cells.

dispersed-dot dither matrix, (i, i + 1) occupy cells that are far from each other.

2	14	3	15
10	6	11	7
4	16	1	13
12	8	9	5

Ordered Dither

Gray scale Image

128	128	128	128	192	192	192	192
128	128	128	128	192	192	192	192
128	128	128	128	192	192	192	192
128	128	128	128	192	192	192	192
64	64	64	64	254	254	254	254
64	64	64	64	254	254	254	254
64	64	64	64	254	254	254	254
64	64	64	64	254	254	254	254

24	216	40	232
152	88	168	104
56	248	8	200
184	120	136	72

4x4 Dither Matrix

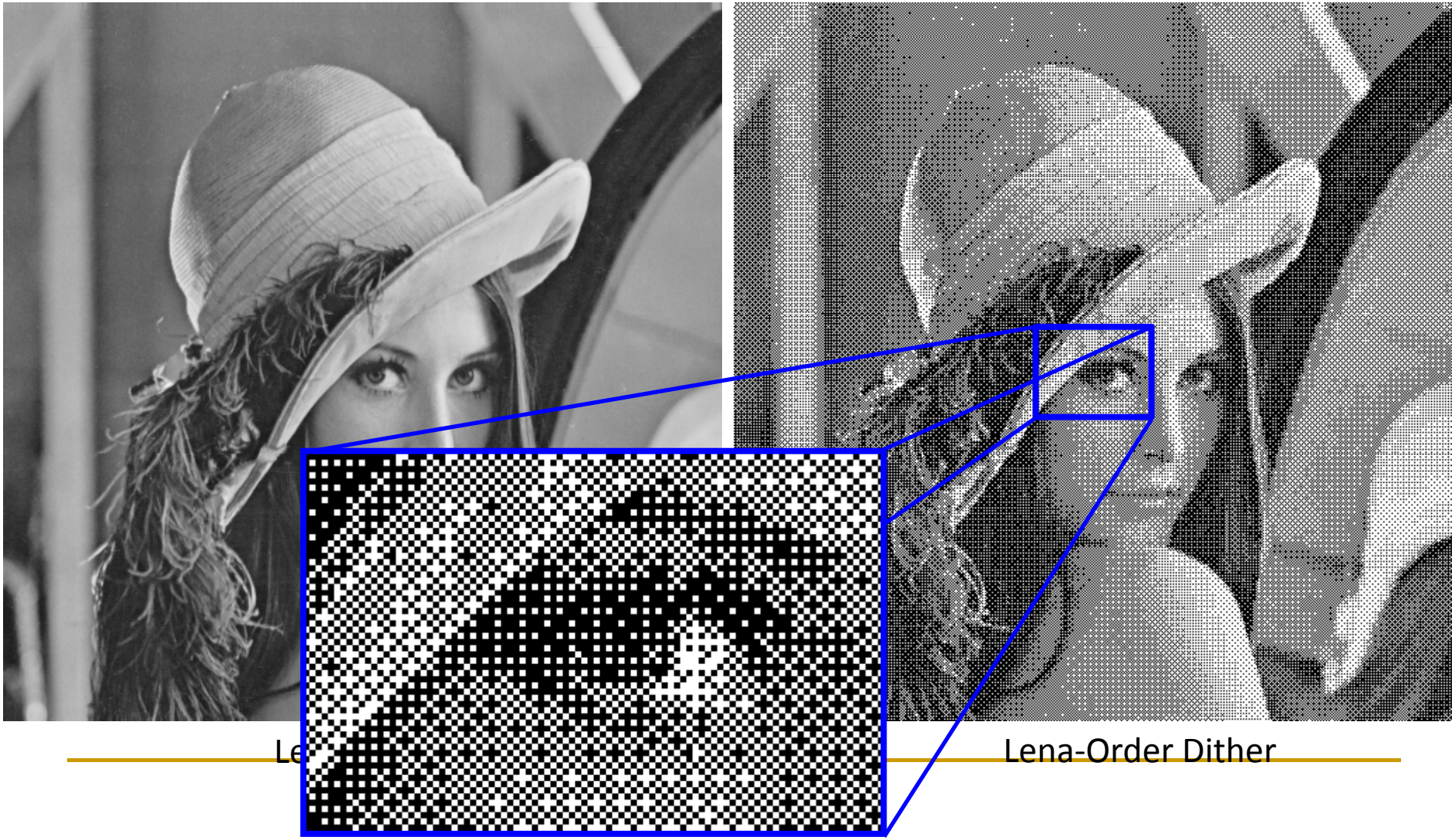
Halftone Image

255	0	255	0	255	0	255	0
0	255	0	255	255	255	255	255
255	0	255	0	255	0	255	0
0	255	0	255	255	255	255	255
255	0	255	0	0	0	0	0
0	0	0	0	0	0	0	0
255	0	255	0	0	0	0	0
0	0	0	0	0	0	0	0

128 > 24 => 255

128 < 216 => 0

Ordered Dither



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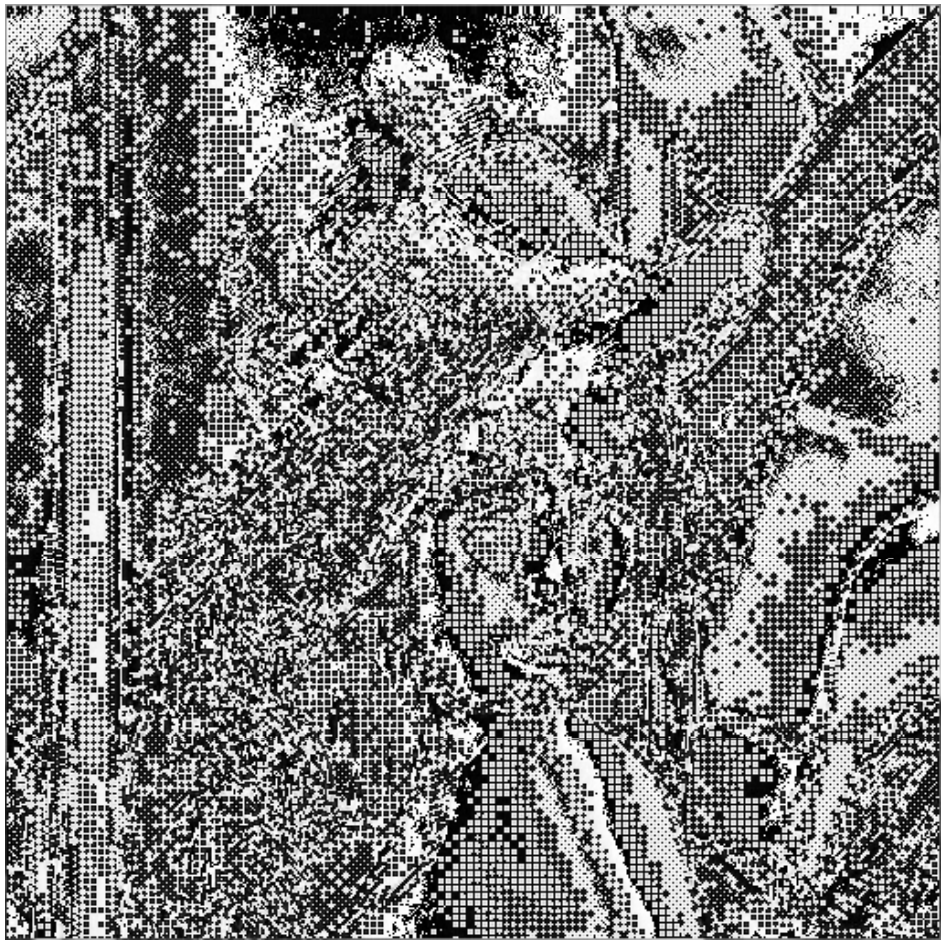
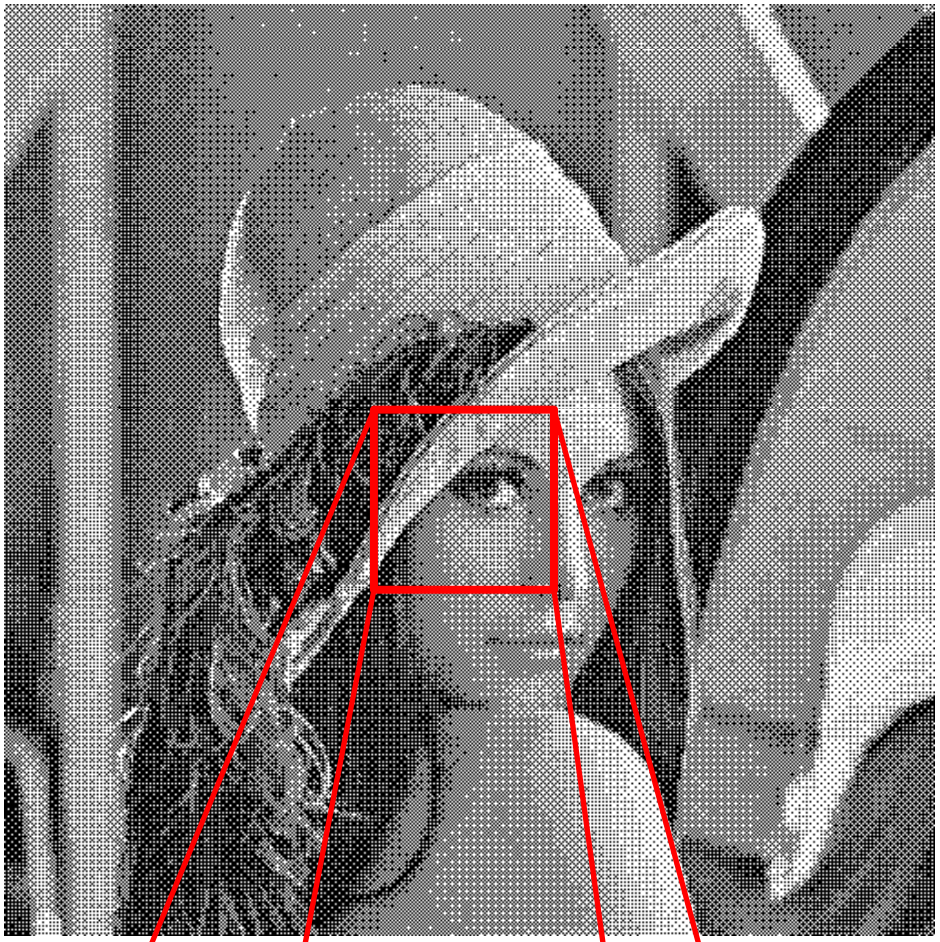
Lena-Order Dither

Lena-Order Dither(LowPass Filter)

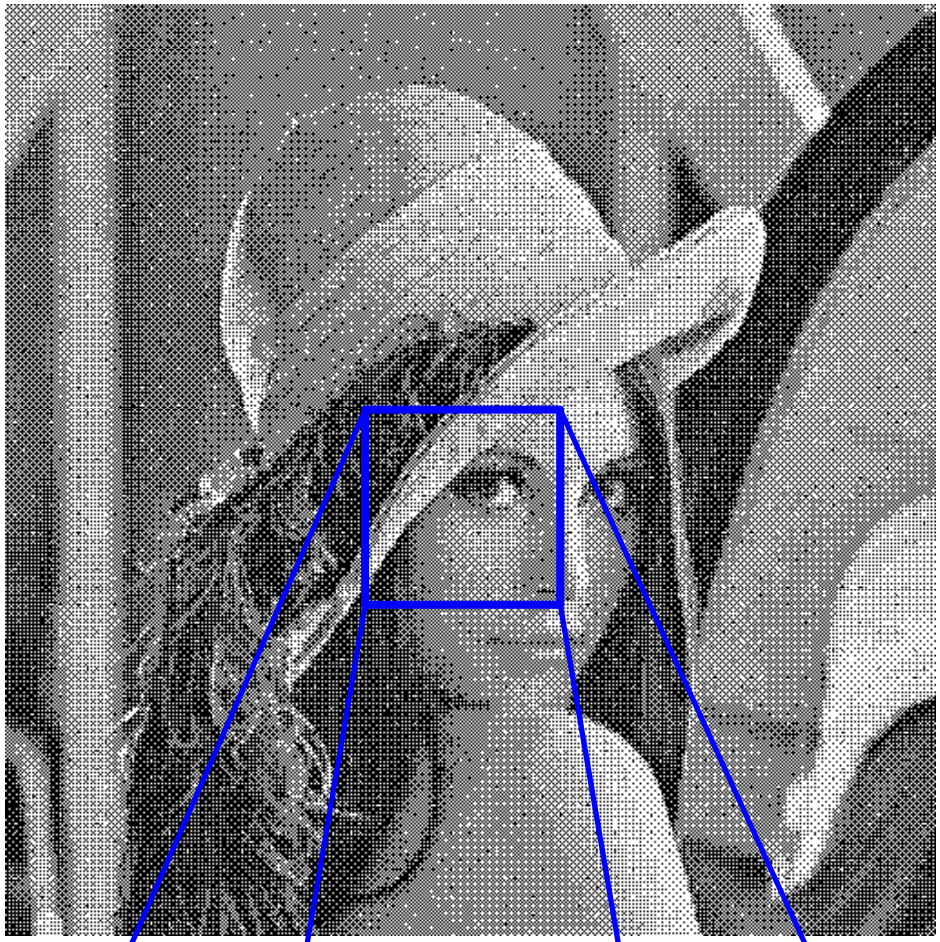


Lena-(256Gray-LowPass Filter)

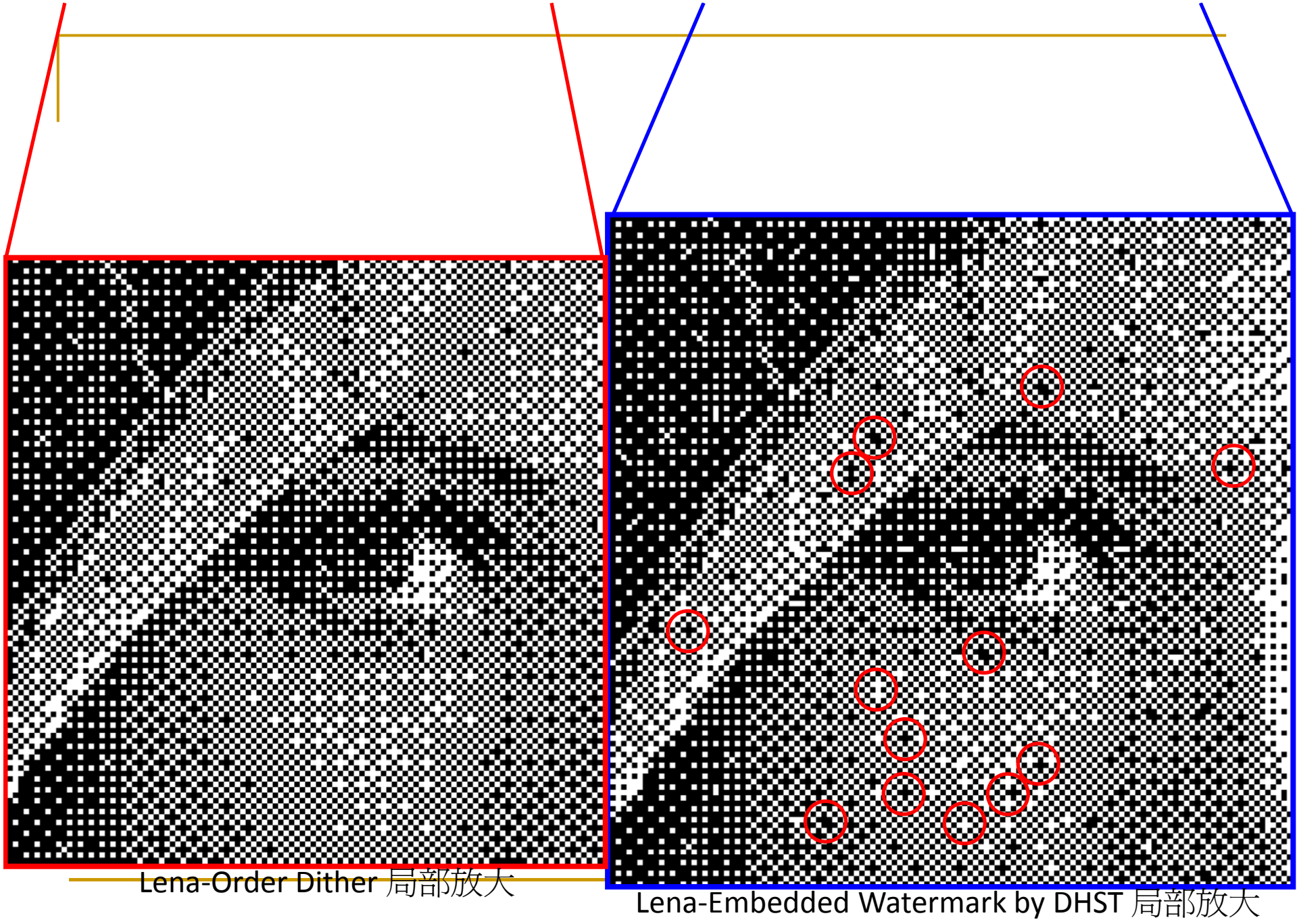
Embedded Watermark by DHST



Lena-Order Dither



Lena-Embedded Watermark by DHST



Lena-Order Dither 局部放大

Lena-Embedded Watermark by DHST 局部放大

Watermarking by Bit Interleaving

Embedding Process

Bit-Interleaving

Sub-image Exchange

Attack

More Bits

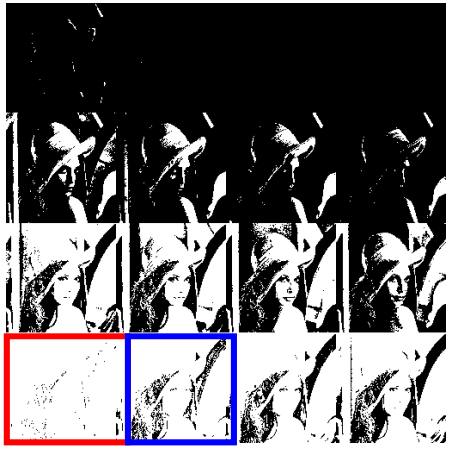
Embedding Process

Original Image

Order-dithering →

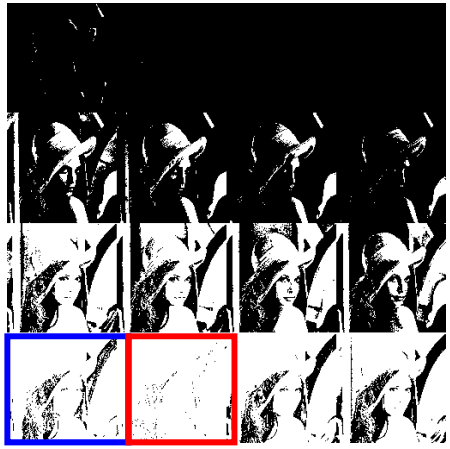
Halftone Image

Bit-Interleaving →



Sub-Image

Embedded →



De-Bit-Interleaving →

Watermarked Image

Swapping

Embedded 1,1,1,1,1,1,0,1

Bit-Interleaving

Bit-Interleaving

2	14	3	15
10	6	11	7
4	16	**1**	13
12	8	**9**	5

2	14	3	15
10	6	11	7
4	16	**1**	13
12	8	**9**	5

2	14	3	15
10	6	11	7
4	16	**1**	13
12	8	**9**	5

2	14	3	15
10	6	11	7
4	16	**1**	13
12	8	**9**	5

Bit-Interleaving

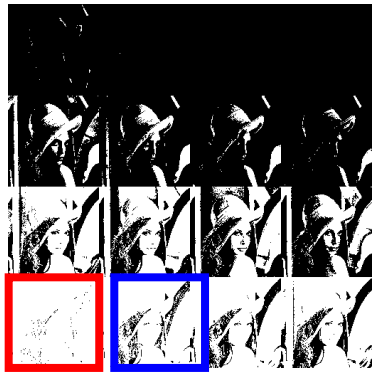
255	0	255	0	255	0	255	0
0	255	0	255	255	255	255	255
255	0	255	0	255	0	255	0
0	255	0	255	255	255	255	255
255	0	255	0	0	0	0	0
0	0	0	0	0	0	0	0
255	0	255	0	0	0	0	0
0	0	0	0	0	0	0	0

24	216	40	232
152	88	168	104
56	248	8	200
184	120	136	72

4x4 Dither Matrix

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	255	0	255	0	255	0	255
0	0	0	0	0	0	0	0
255	255	255	255	255	255	255	255
0	0	0	0	0	0	0	0
255	255	255	255	255	255	255	255
255	0	255	0	255	0	255	0

→



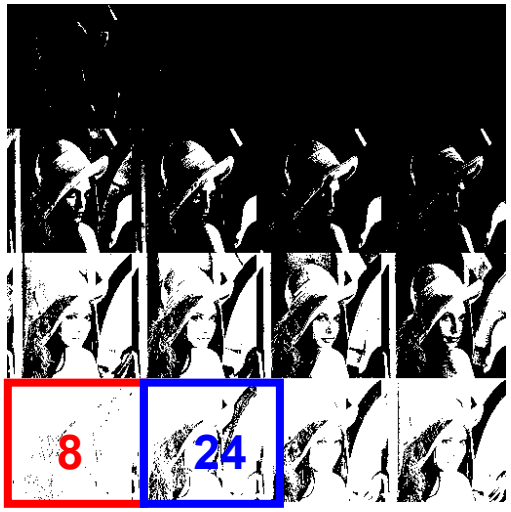
Bit-Interleaving

Bit-Interleaving

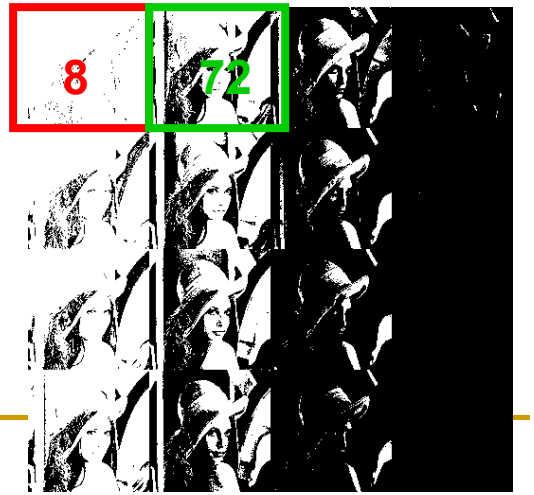
24	216	40	232
152	88	168	104
56	248	8	200
184	120	136	72

4x4 Dither Matrix

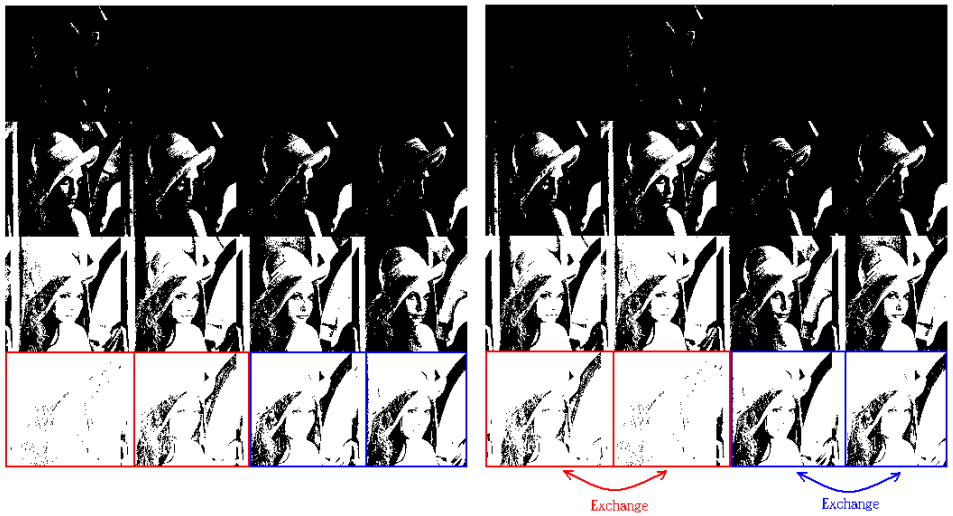
1span →



4span →



Sub-image Exchange

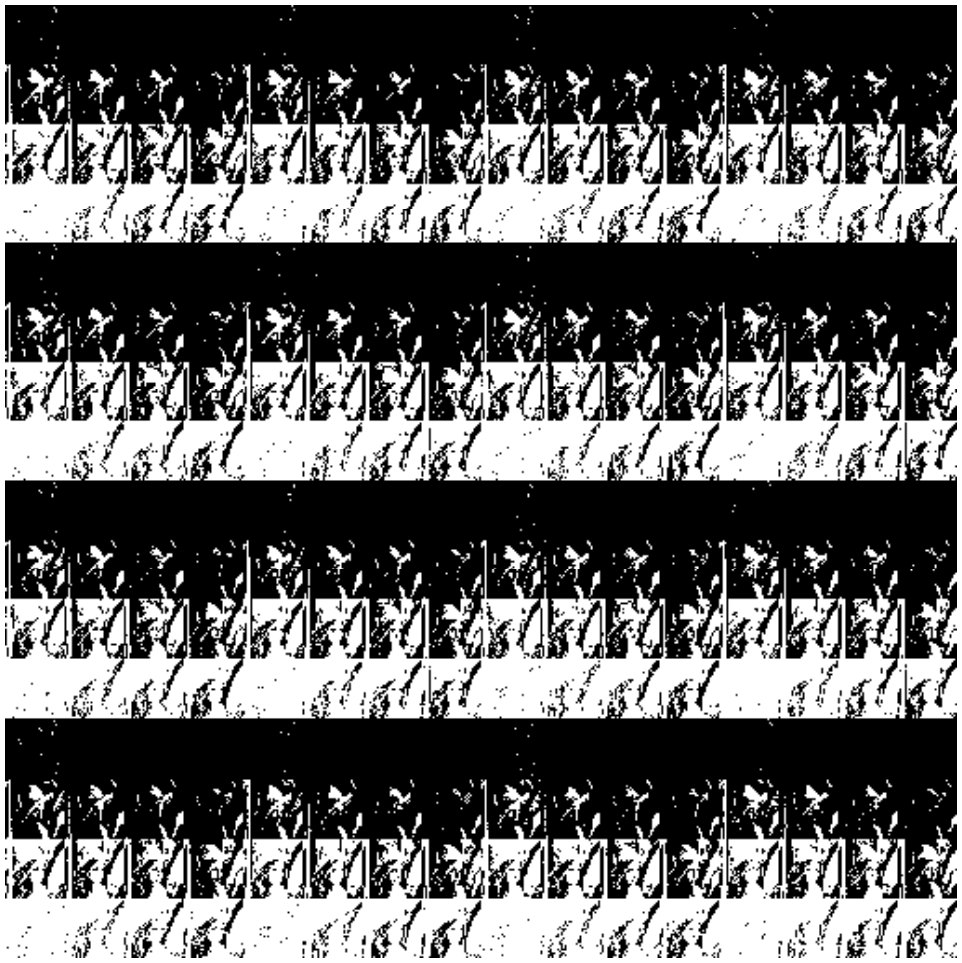


2	14	3	15
10	6	11	7
4	16	**1**	13
12	8	**9**	5

Sub-image Exchange

Attack

More Bits



THANK YOU!