Halftoning

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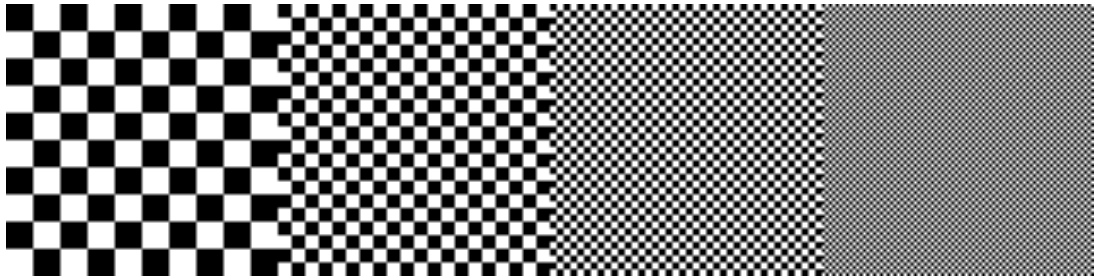

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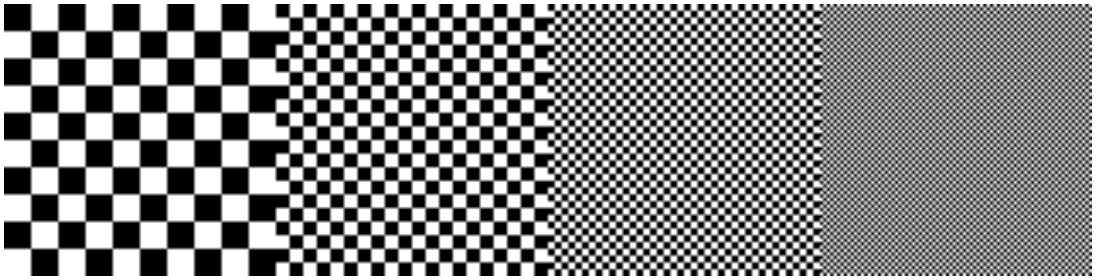
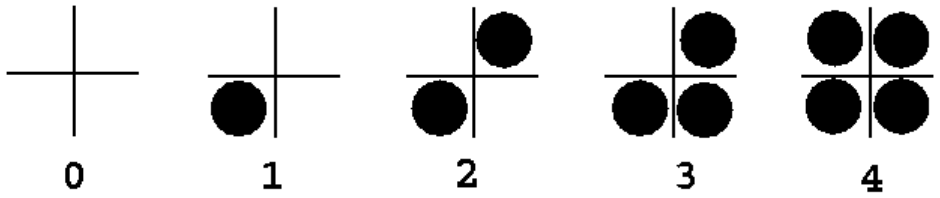


Represent each pixel in the input image using an $n \times n$ grid of pixels in the halftoned image

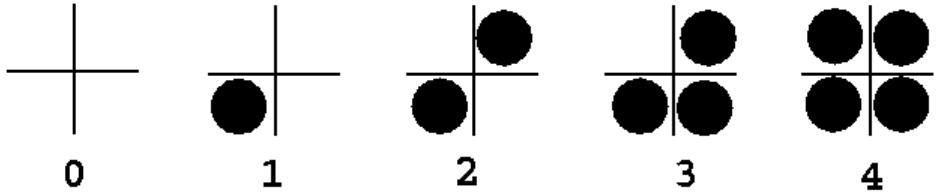
$n = 2$



5 levels

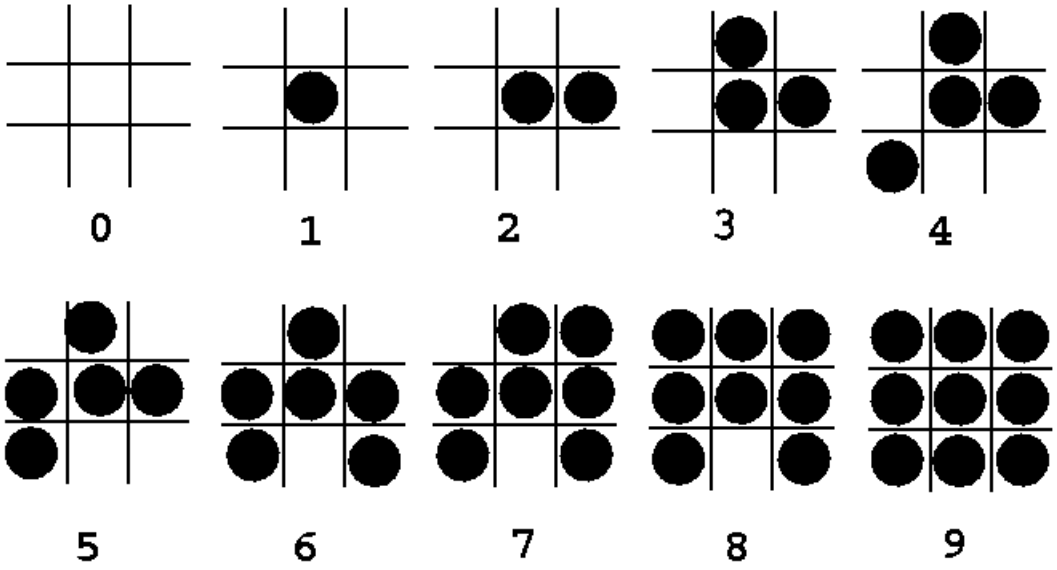
Represent each pixel in the input image using an n x n grid of pixels in the halftoned image

n = 2



5 levels

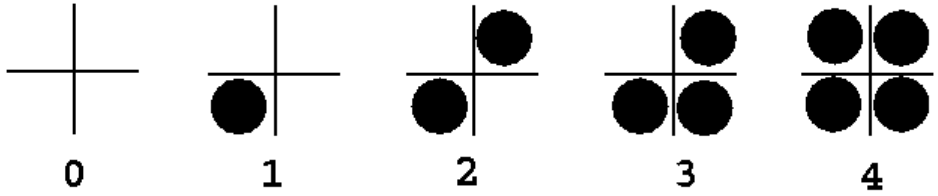
n = 3



10 levels

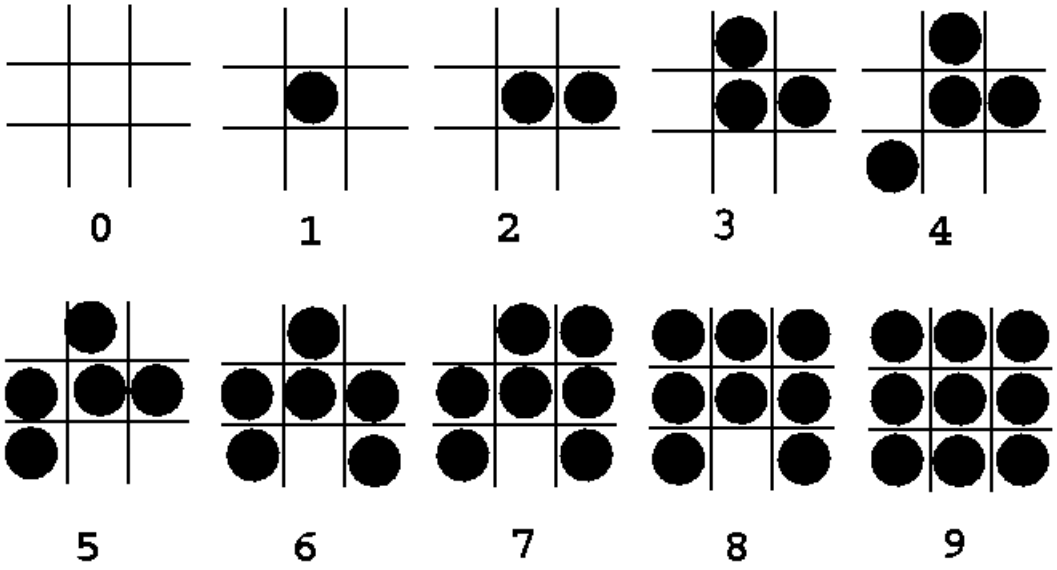
Represent each pixel in the input image using an $n \times n$ grid of pixels in the halftoned image

$n = 2$



5 levels

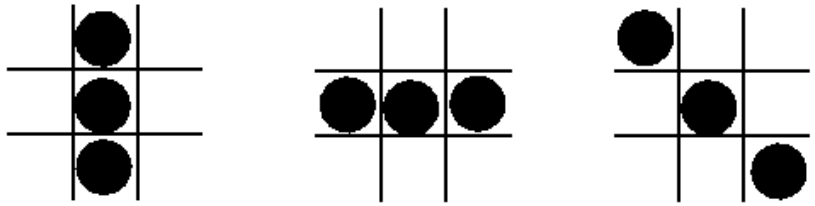
$n = 3$



10 levels

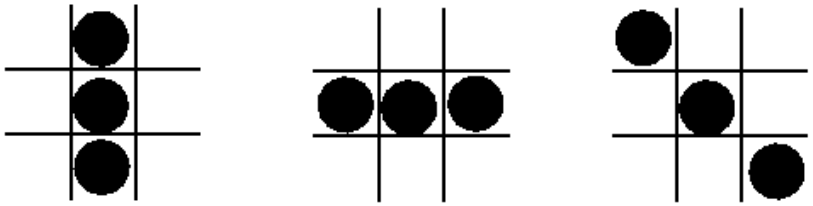
Halftoning turns a bilevel display into an n^2+1 level display.

Patterns like



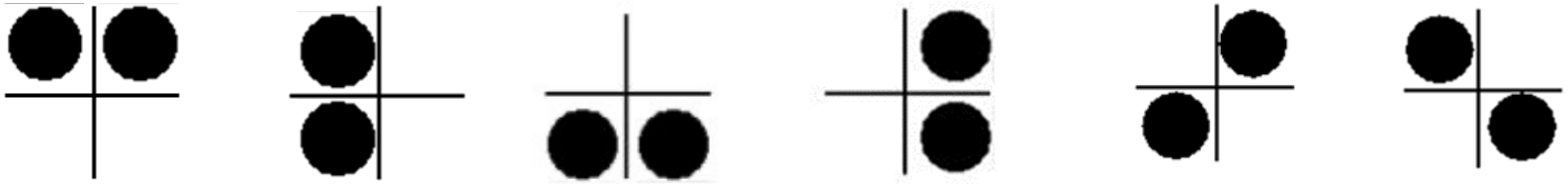
cause unwanted structure in image regions of constant intensity

Patterns like



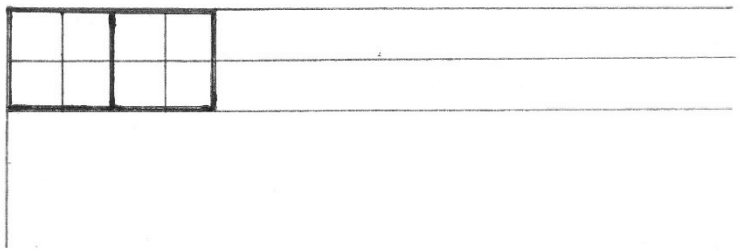
cause unwanted structure in image regions of constant intensity

Can use several patterns to represent an intensity level if these are alternated



(Ex) Consider a 512x512 pixel bilevel display

Suppose 2x2 pixel blocks on the display represent one pixel in the halftoned image.



The halftoned image is 256x256 with 5 levels per pixel.

Halftoning also improves the intensity resolution of displays with more than 2 levels.

(Ex) 2x2 grid, 2 bits (4 levels) per display pixel

$\Rightarrow$ 13 intensity levels per halftoned pixel

0	0		0	1		0	1					3	3		
0	0		0	0		1	0		…			3	3		
0			1			2			…			12			

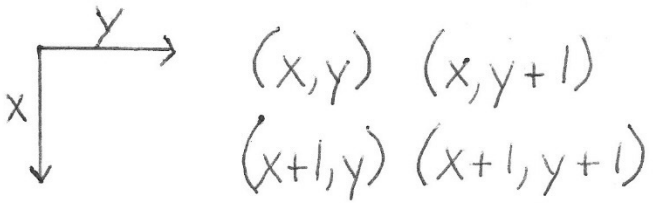
Error Distribution

Scan left to right and top to bottom

For each input image pixel $G(x,y)$,
Compute the best halftone approximation $H(x,y)$

$$Error(x,y) = G(x,y) - H(x,y)$$

$$G(x,y+1) = G(x,y+1) + \frac{3}{8} * Error(x,y)$$
$$G(x+1,y) = G(x+1,y) + \frac{3}{8} * Error(x,y)$$
$$G(x+1,y+1) = G(x+1,y+1) + \frac{2}{8} * Error(x,y)$$



Error is distributed to the right and down.

(Ex) Map the input 2x2 image with gray levels from 0 to 260 to a halftoned 4 x 4 2 bit/pixel image using Error Distribution

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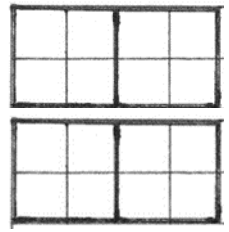
62	100
120	220



(Ex) Map the input 2x2 image with gray levels from 0 to 260 to a halftoned 4 x 4 2 bit/pixel image using Error Distribution

62	100
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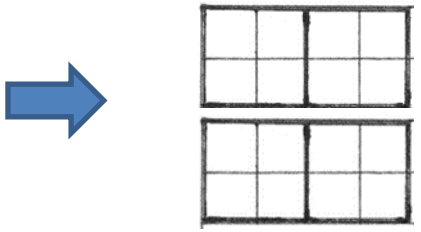

Map 0 to 260 to 0 to 12

H	Range of G	Avg G
0	0-20	10
1	20-40	30
2	40-60	50
3	60-80	70
4	80-100	90
5	100-120	110
6	120-140	130
7	140-160	150
8	160-180	170
9	180-200	190
10	200-220	210
11	220-240	230
12	240-260	250

Boundary G values (e.g. 100) are assigned to smaller H (e.g. 4)

upper left $G(x,y) = 62$ $H(x,y) = 3 \longrightarrow 70$

$Error(x,y) = G(x,y) - H(x,y) = 62 - 70 = -8$

$\frac{3}{8} * Error(x,y) = -3$ $\frac{2}{8} * Error(x,y) = -2$

New $G(x,y)$

62	97
117	218

upper left $G(x,y) = 62$ $H(x,y) = 3 \longrightarrow 70$

$Error(x,y) = G(x,y) - H(x,y) = 62 - 70 = -8$

$\frac{3}{8} * Error(x,y) = -3$ $\frac{2}{8} * Error(x,y) = -2$

New $G(x,y)$

62	97
117	218

upper right $G(x,y) = 97$ $H(x,y) = 4 \longrightarrow 90$

$Error(x,y) = G(x,y) - H(x,y) = 97 - 90 = 7$

$\frac{3}{8} * Error(x,y) = 2.625$ $\frac{2}{8} * Error(x,y) = 1.75$

New $G(x,y)$

62	97
117	220.625

lower left $G(x,y) = 117$ $H(x,y) = 5 \longrightarrow 110$

$Error(x,y) = G(x,y) - H(x,y) = 117 - 110 = 7$

$\frac{3}{8} * Error(x,y) = 2.625$ $\frac{2}{8} * Error(x,y) = 1.75$

New $G(x,y)$

62	97
117	223.25 $\longrightarrow$ 11

lower left $G(x,y) = 117$ $H(x,y) = 5 \longrightarrow 110$

$Error(x,y) = G(x,y) - H(x,y) = 117 - 110 = 7$

$\frac{3}{8} * Error(x,y) = 2.625$ $\frac{2}{8} * Error(x,y) = 1.75$

New $G(x,y)$

62	97
117	223.25 $\longrightarrow$ 11

Halftoned Image

3	4	$\longrightarrow$	1	1	1	1
5	11		0	1	1	1
			1	1	3	3
			2	1	2	3