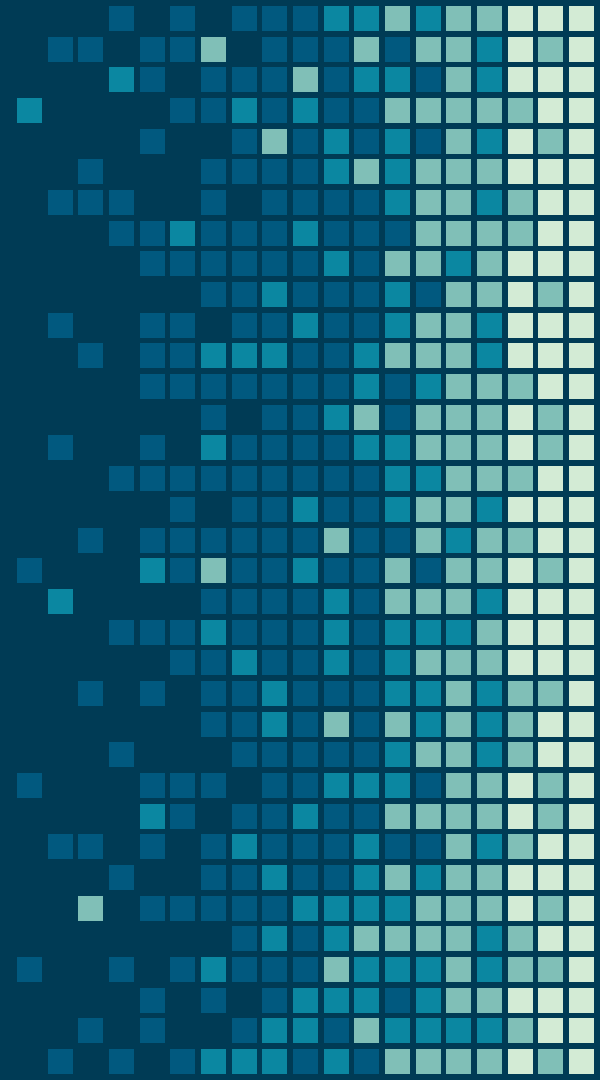


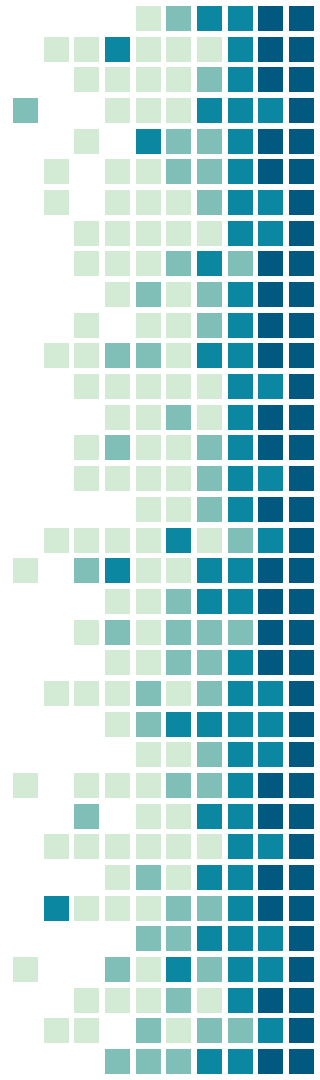
Dithering

Ryan Greenwalt and Manu Atwal



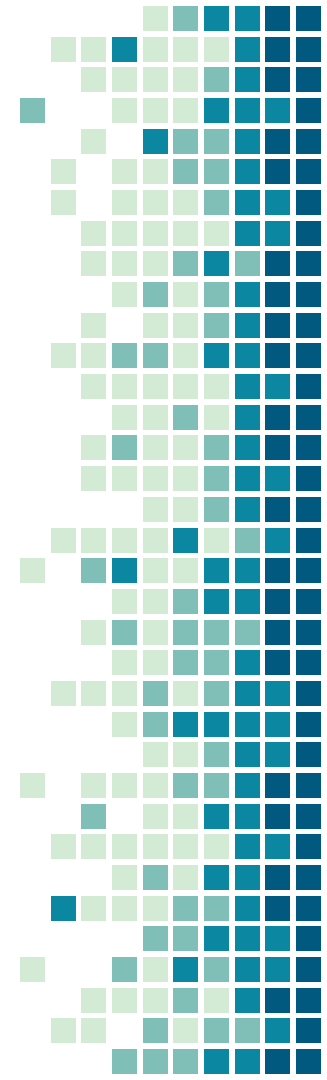
Dithering

- **A technique that blends available pixel colors in patterns to simulate smoother gradients and expand the color depth.**

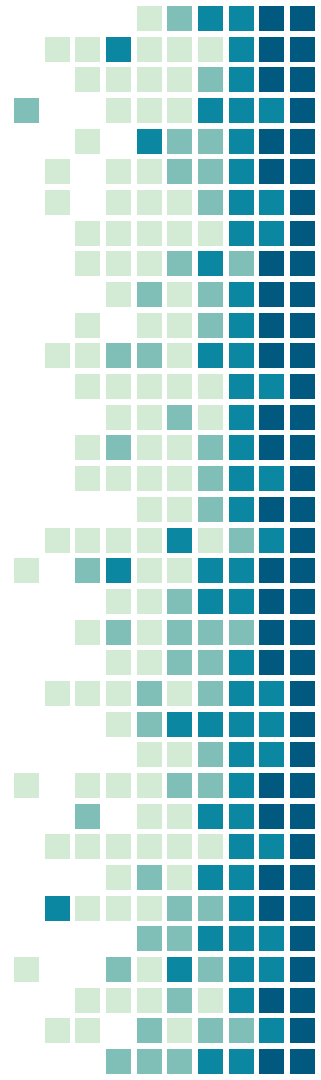
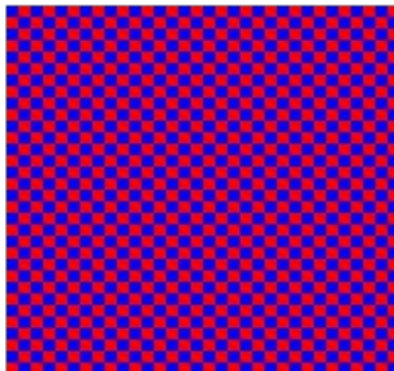
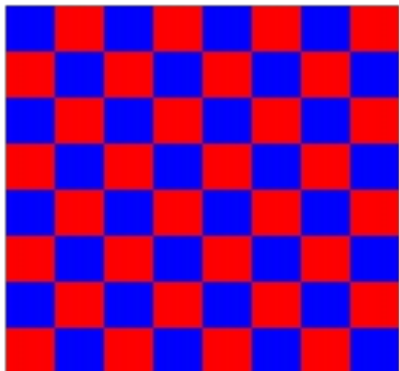
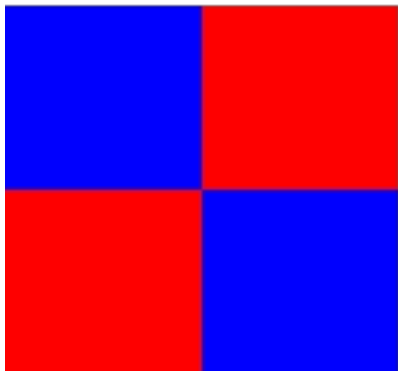
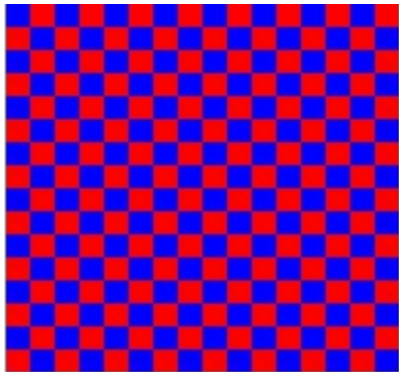
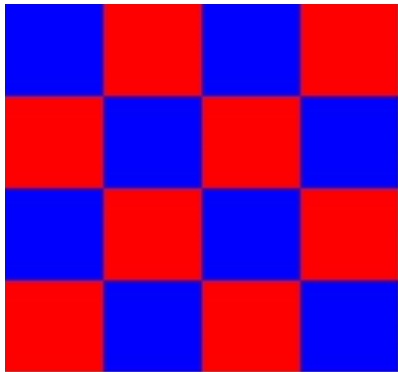


Usage

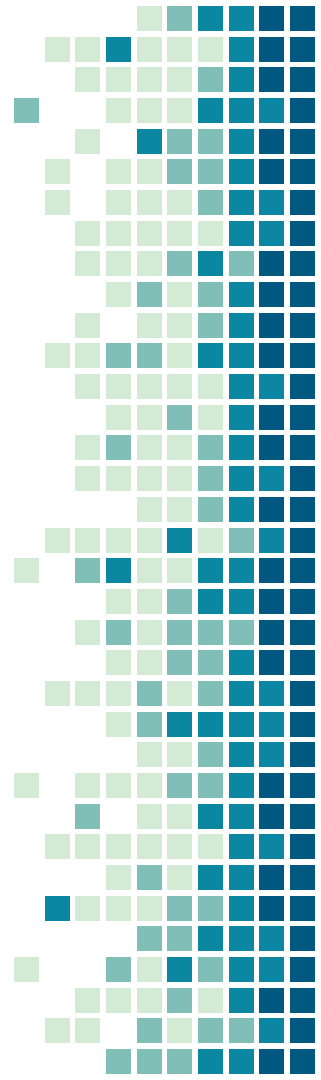
- **Limited video hardware? No problem!**
- **Audio processing.**



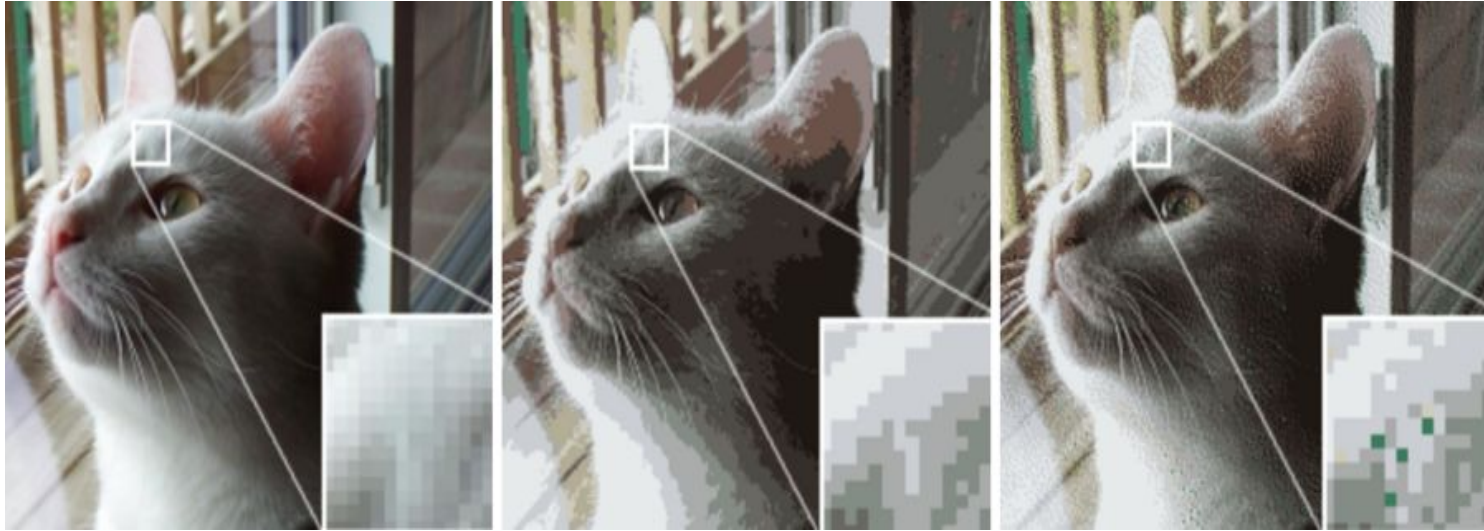
Examples (1)



Examples (2)



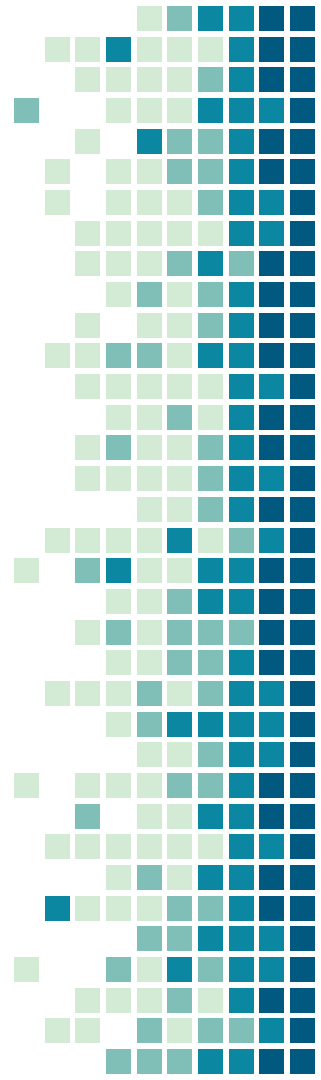
Examples (3)



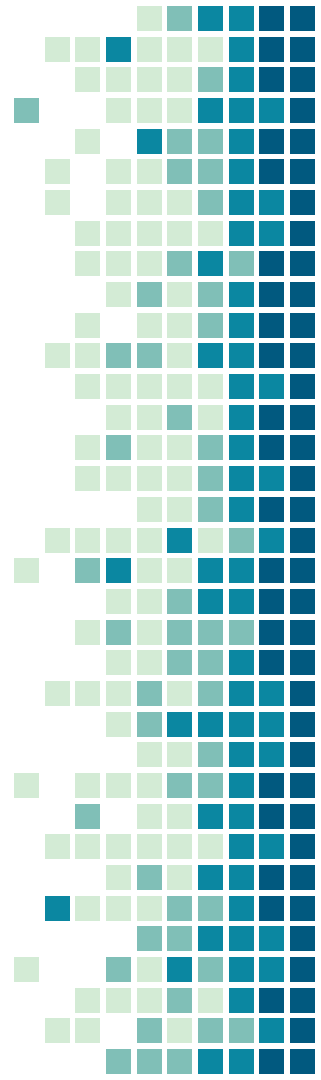
Original image.

Reduced to 16 colors.

***Dithering applied to
the second image.***



Examples (4)



Thresholding



Threshold = 0.5



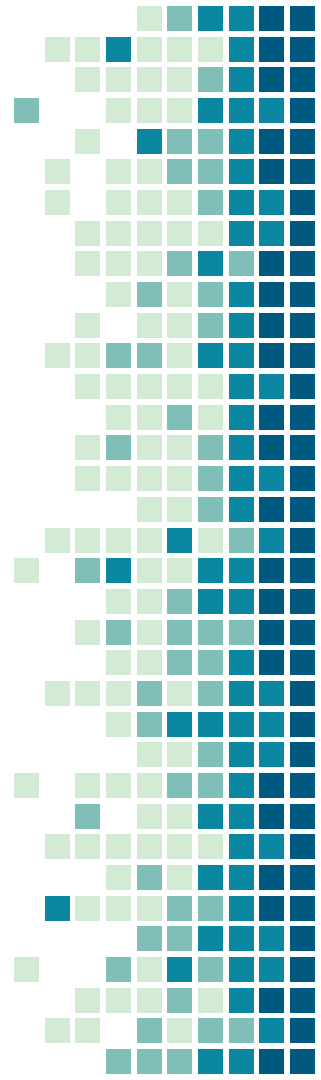
Original



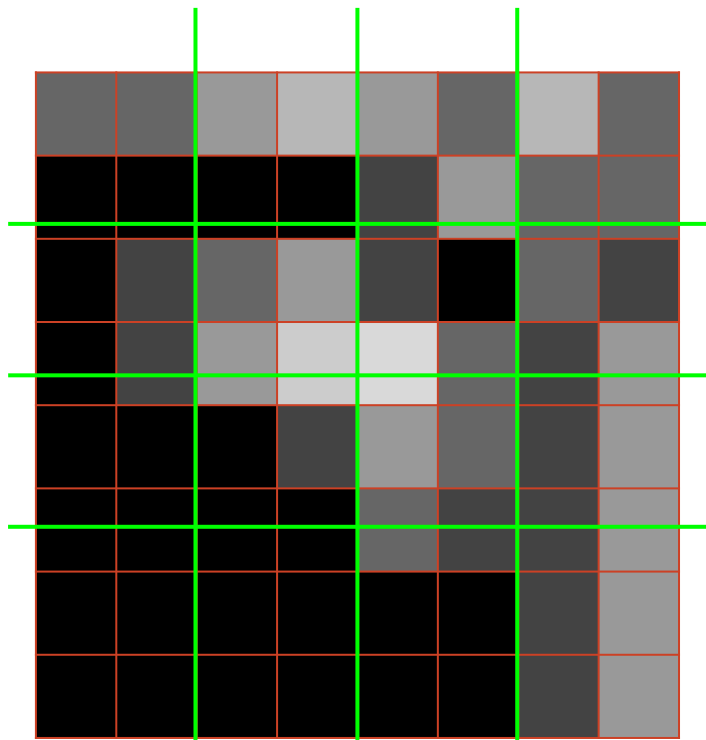
Threshold



Random Threshold



Ordered Dithering

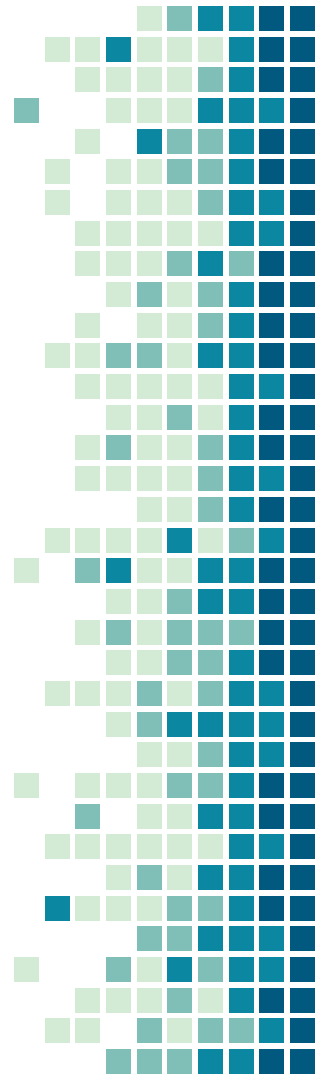


$$M = \frac{1}{4} \begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$



$$\begin{bmatrix} 0.0 & 0.5 \\ 0.75 & 0.25 \end{bmatrix}$$

Threshold Matrix



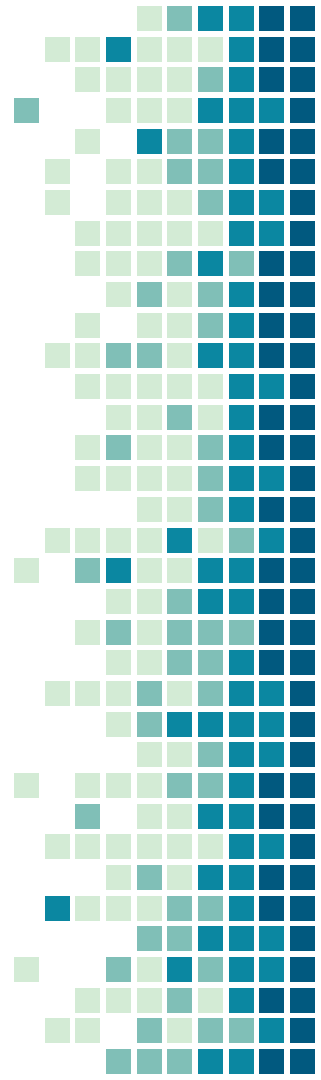
Ordered Dithering Activity

0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1
0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1
0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1
0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1
0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1
0	0.1	0.15	0.25	0.4	0.5	0.6	0.75	0.9	1

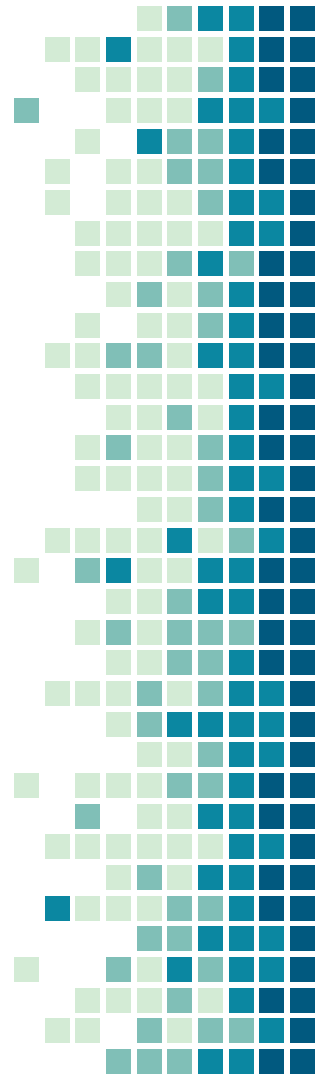
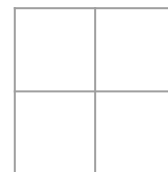
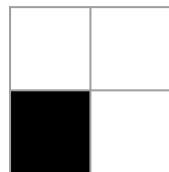
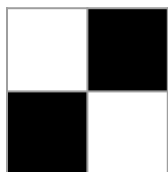
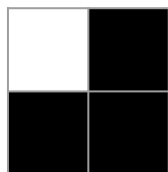
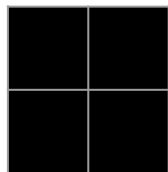
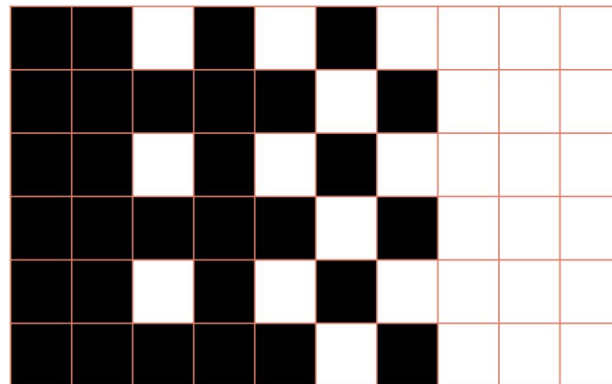
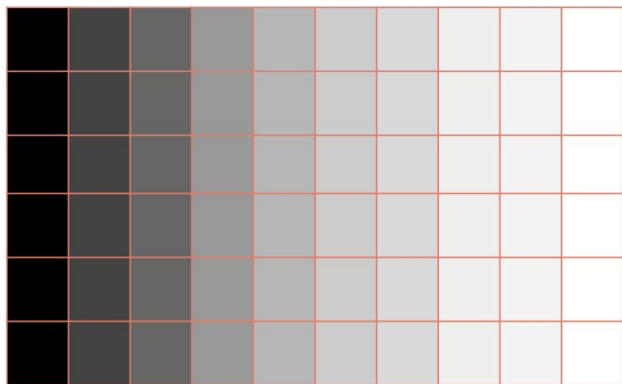
$$\begin{bmatrix} 0.0 & 0.5 \\ 0.75 & 0.25 \end{bmatrix}$$



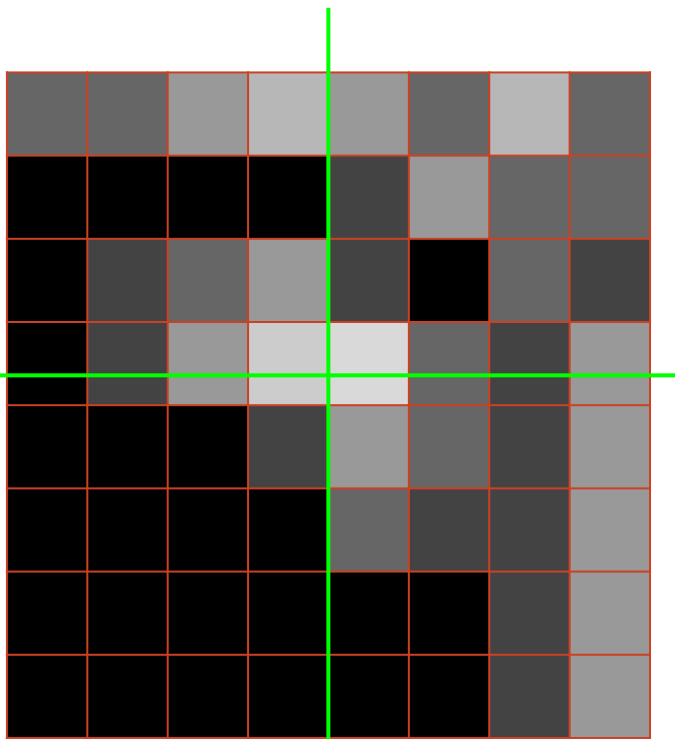
- If the pixel value is less than or equal to the corresponding threshold, color it in.
- Otherwise, leave it blank.



Ordered Dithering Activity

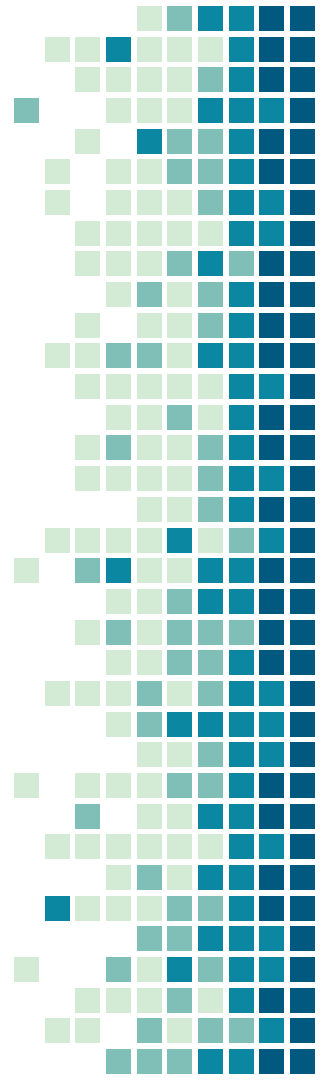


Ordered Dithering



$$M = \frac{1}{16} \begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$

$$M_{2n} = \frac{1}{(2n)^2} \begin{bmatrix} (2n)^2 M_n & (2n)^2 M_n + 2J_n \\ (2n)^2 M_n + 3J_n & (2n)^2 M_n + J_n \end{bmatrix}$$



Ordered Dithering

Original



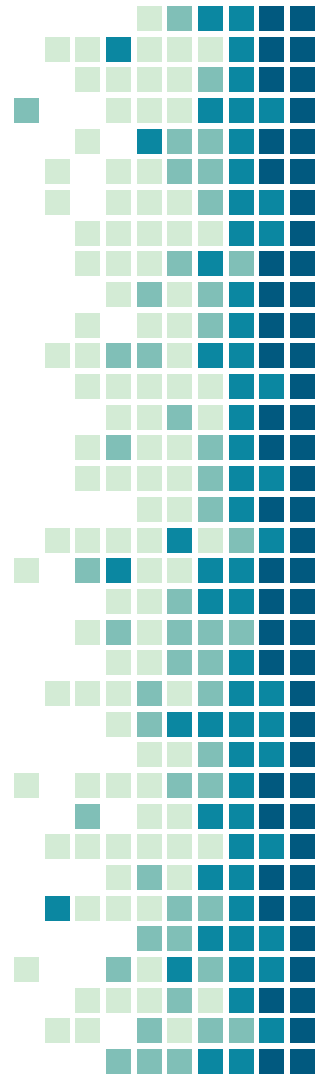
Threshold



Random Threshold



Ordered



Error Diffusion Dithering

- **Push (add) the residual quantization error of a pixel onto its neighboring pixels, to be dealt with later.**

0.3



0

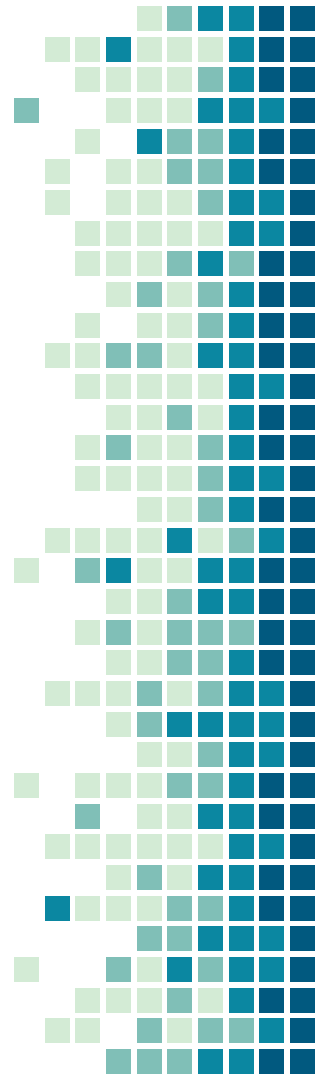
error = +0.3

0.8



1

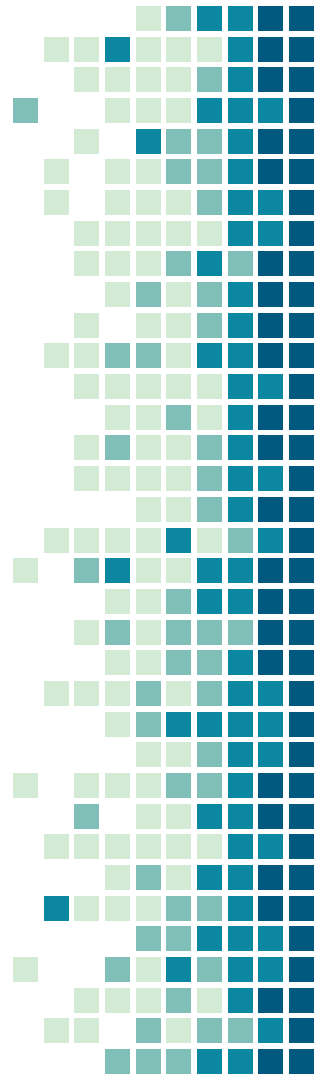
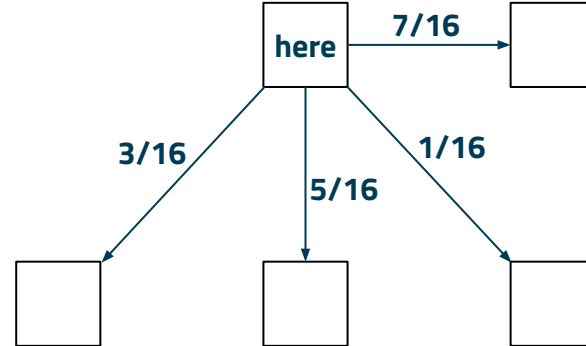
error = -0.2



Floyd-Steinberg (1975)

for each pixel p

```
new_color = closest_palette_color(p)
error = p.color - new_color
p.color = new_color
add (7/16 * error) to right neighbor
add (3/16 * error) to bottom left neighbor
add (5/16 * error) to bottom neighbor
add (1/16 * error) to bottom right neighbor
```



Floyd-Steinberg (1975)

Original



Threshold



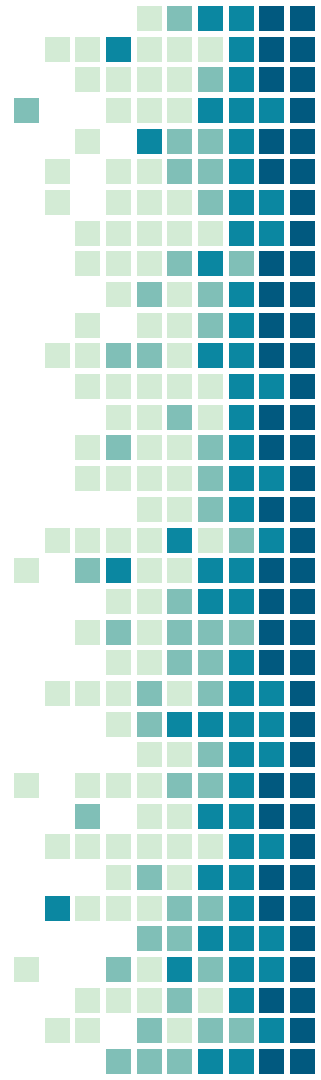
Random Threshold



Ordered



Floyd-Steinberg



Questions?

