Halftone (I)

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What is digital halftoning?

- Halftoning is a method for creating the *illusion* of continuous tone output with a binary device or a low resolution device.

- Effective digital halftoning can substantially improve the quality of rendered images at minimal cost.
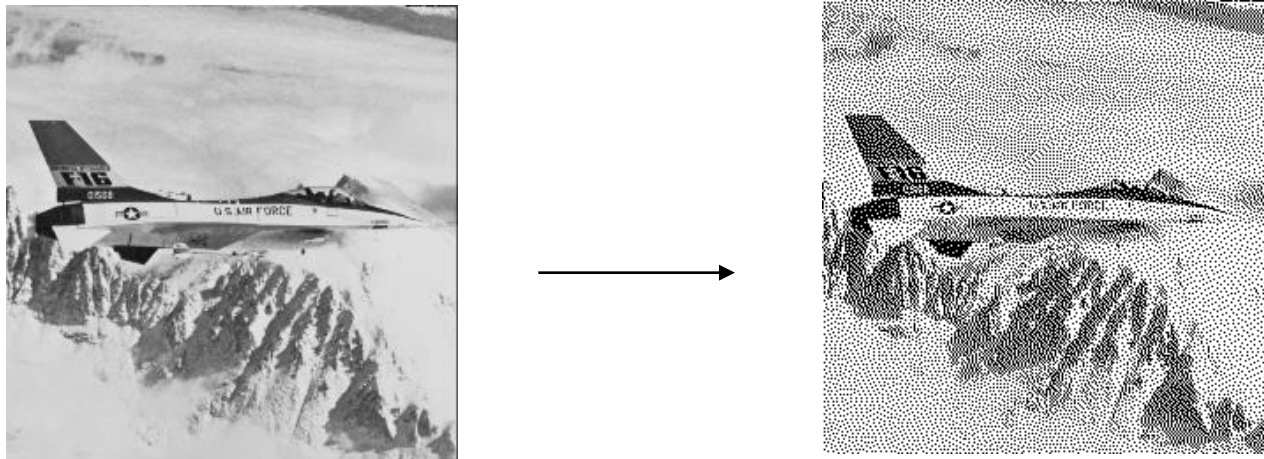
Fig.1 An example for halftoning process

Need for Digital Image Halftoning

- Examples of reduced grayscale/color resolution
  - Laser and inkjet printers
  - Facsimile machines
  - Low-cost liquid crystal displays

- Halftoning is word-length reduction for images
  - Grayscale: 8-bit to 1-bit **(binary)**
  - Color displays: 24-bit RGB to 12-bit RGB **(e.g. PDA/cell)**
  - Color displays: 24-bit RGB to 8-bit RGB **(e.g. cell phones)**
  - Color printers: 24-bit RGB to CMYK **(each color binarized)**

- Halftoning tries to reproduce full range of gray/color while preserving quality & spatial resolution
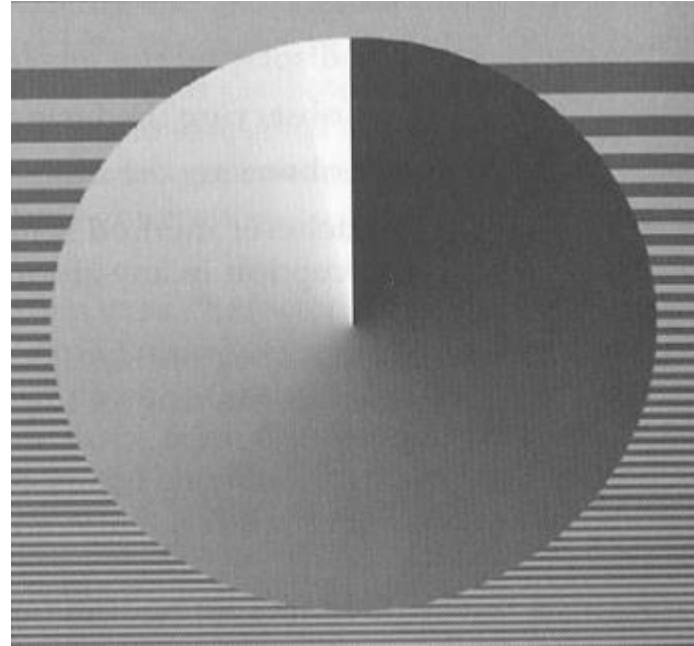
Halftone Methods

- Threshold Dithering
- Random Modulation
- Ordered Dithering [1, Bayer, 1973]
  - Cluster dot screen
  - Disperse dot screen
- Error Diffusion [2, Floyd and Steinberg, 1975]

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Sample Images

Threshold Dithering

- For every pixel: If the intensity < 0.5, replace with black, otherwise replace with white
  - 0.5 is the threshold
  - This is the naïve version of the algorithm
- To keep the overall image brightness the same, you should:
  - Compute the average intensity over the image
  - Use a threshold that gives that average
  - For example, if the average intensity is 0.6, use a threshold that is higher than 40% of the pixels, and lower than the remaining 60%. (For a halftone of a constant gray image, the gray level value specifies the proportional of black dots over a white background no matter how the dots are to be arranged.)
- For all dithering we will assume that the image is gray and that intensities are represented as a value in [0, 1.0]
  - If you have a 0-255 image, you can scale all the thresholds (multiply by 255)

Naïve Threshold Algorithm
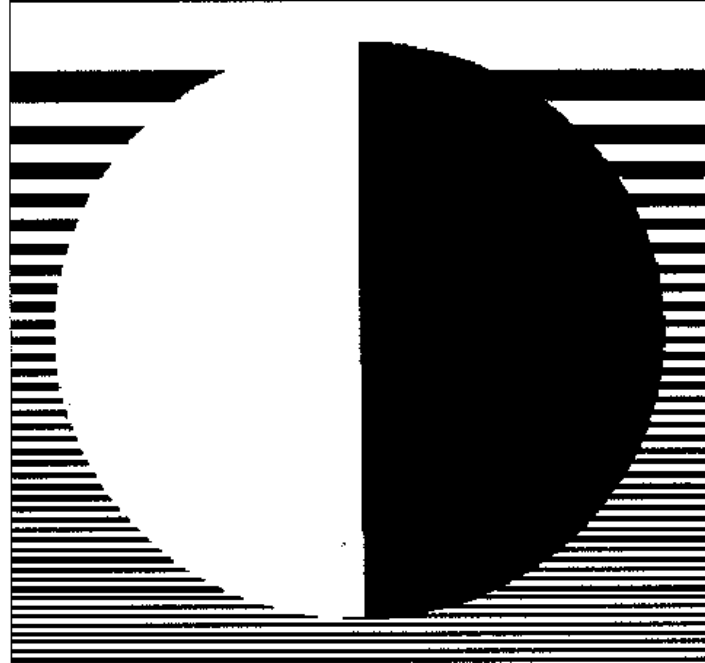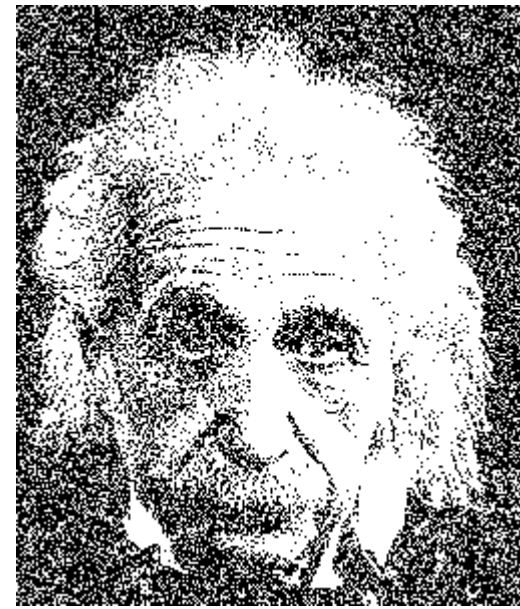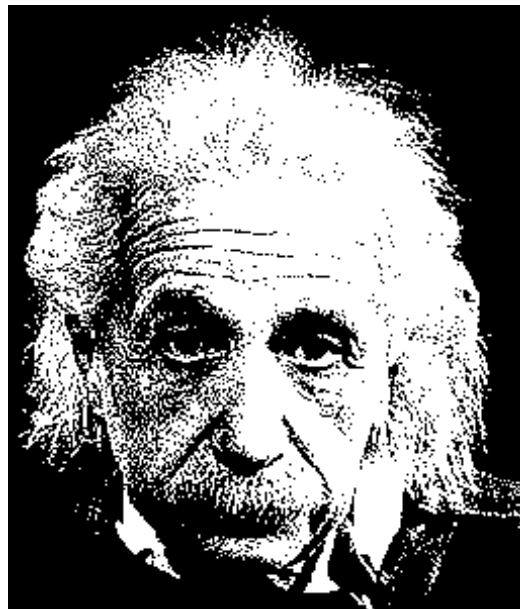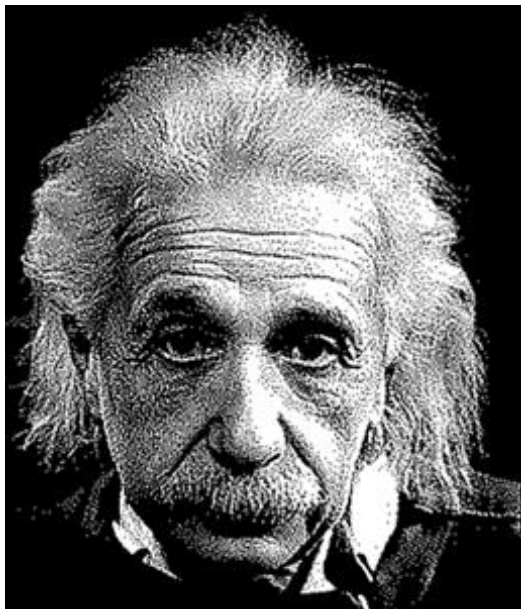
Original Gray Images   Threshold = average gray vale   Tone-preserving halftoned

Pointillism (点画法)

- Several artists over the last hundred years have utilized halftone in paintings by using stippling.

- In these paintings, artists put dots of primary or complimentary colors on the canvas to achieve a certain color blend when viewing the painting at a distance.

- This approach, which is known as *pointillism*, contrasts with the conventional approach of mixing colors on a palette before applying the paint using sweeping and fine strokes.

- Pointillism was a French movement of the late 1800s that was an offshoot of impressionism.

"The Channel of Gravelines, Evening"
(1890) by Georges-Pierre Seurat
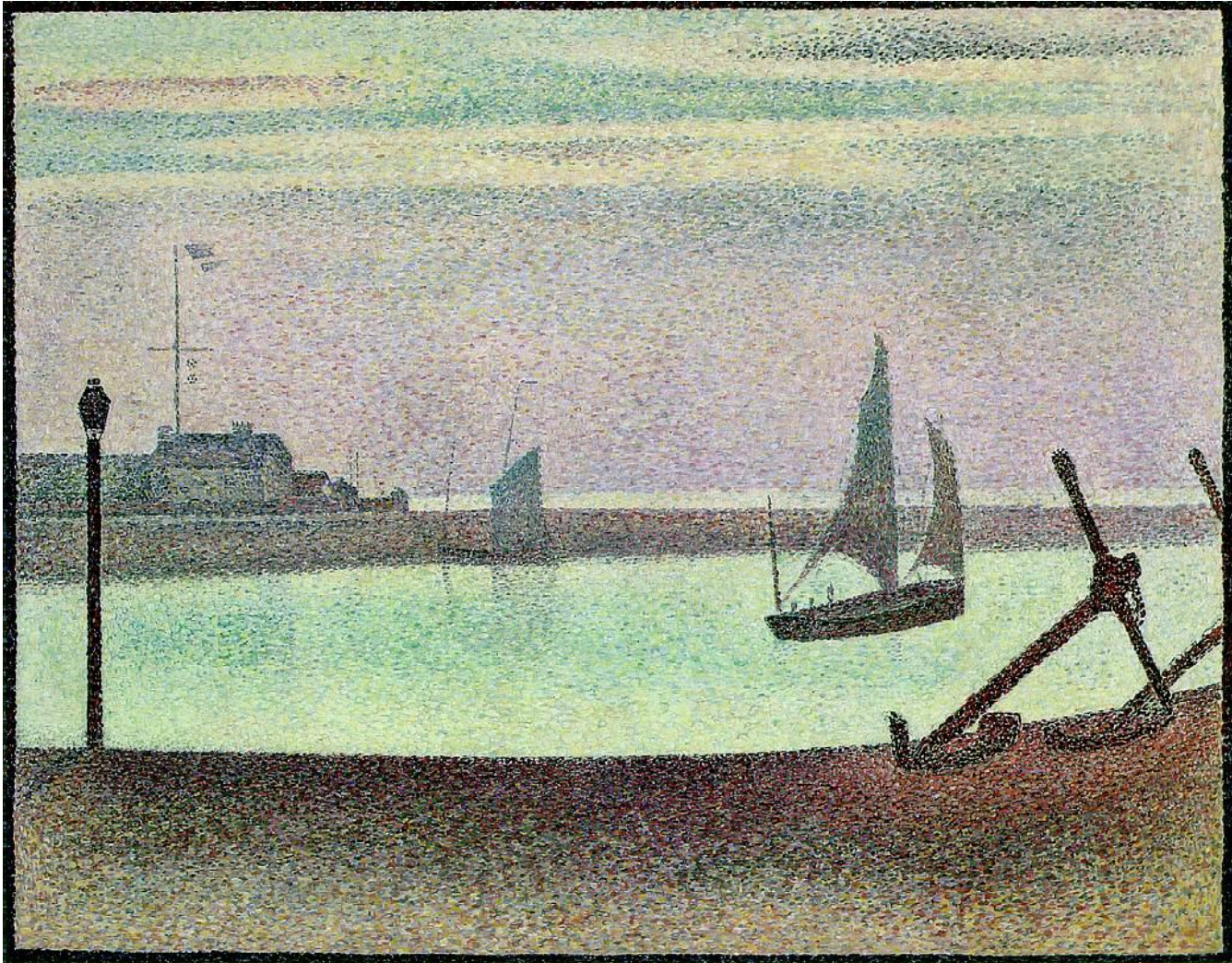
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Random Modulation

- Add a random amount to each pixel *before* thresholding
  - Typically add *uniformly* random amount from [-*a*, *a*]
- Pure addition of noise to the image
  - For better results, add better quality noise
  - For instance, use Gaussian noise (random values sampled from a normal distribution)
- Should use same procedure as before for choosing threshold
- Not good for black and white, but **OK** for more colors
  - Add a small random color to each pixel before finding the closest color in the table

Random Modulation
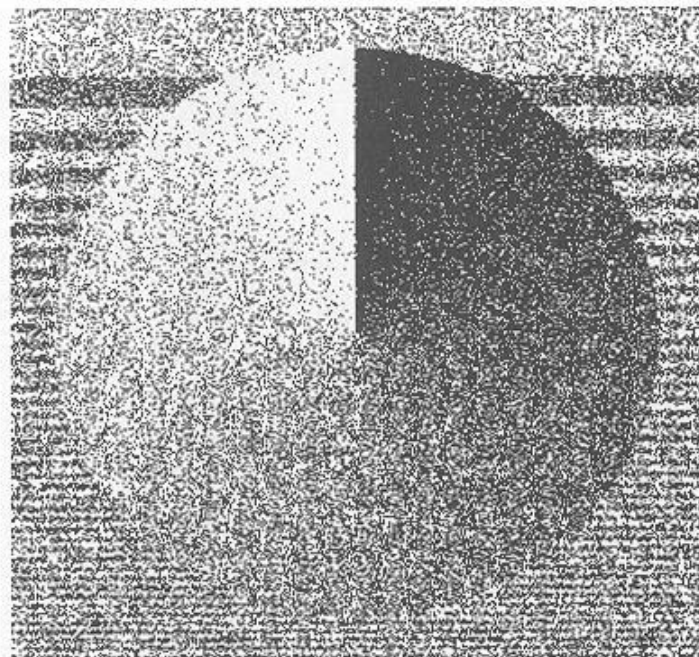
References

- [1]   B. E. Bayer, "An optimum method for two-level rendition of continuous-tone pictures," in Proceedings of the IEEE International Conference on Communication, pp. 11-26, 1973.
- [2]   R. Floyd and L. Steinberg, "An adaptive algorithm for spatial grey scale," Society for Information Display Symposium, Digest of Technical Papers, pp.36-37, 1975.

Thank You!

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