Image Noise and Filtering

CS/BIOEN 4640: Image Processing Basics

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Types of Image Noise

- Thermal Noise (additive Gaussian noise)
- Shot noise (random counts, Poisson noise)
- Salt-and-Pepper (replacement noise)
- Rician noise (magnitude of 2D Gaussian, MRI)

Thermal Noise

- Thermal noise (or Johnson-Nyquist noise) is due to random fluctuations of electrons.
- When the signal from a photosensor is amplified, this noise is also amplified.
- “ISO level” controls the amount of amplification on digital cameras.
- Especially a problem in low-light situations – more amplification needed.
- Noise also gets worse with smaller sensor size and with denser packing of pixels.

Thermal Noise as Additive Gaussian Noise

- Thermal noise is modeled as a Gaussian random value, ϵ, added to the signal, s:

$$s' = s + \epsilon$$

- The random variable ϵ has mean zero
- The random noise at each pixel is independent of other pixels
- The noise level (σ in Gaussian) is equal at all pixels

Shot Noise

- Remember the photodiode signal strength is proportional to the number of photons that hit the sensor
- Photons hitting the sensor is a random process
- Shot noise is the noise due to this “counting” of a random number of photons
- Follows a Poisson distribution – can be approximated by a Gaussian

Salt-and-Pepper Noise

- Also called “replacement” noise because some percentage of pixel values are just replaced by random numbers
- Example: “dead pixels” appear mostly dark due to defective sensor
- Example: “hot pixels” appear as overly bright pixels, due to charge leakage in long exposures

Noise in Magnetic Resonance Imaging

- MRI is acquired in two channels
- Both channels are corrupted by additive Gaussian noise
- However, the image we view is the magnitude of the combined channels
- The resulting noise is Rice distributed
- It is not additive and not mean zero

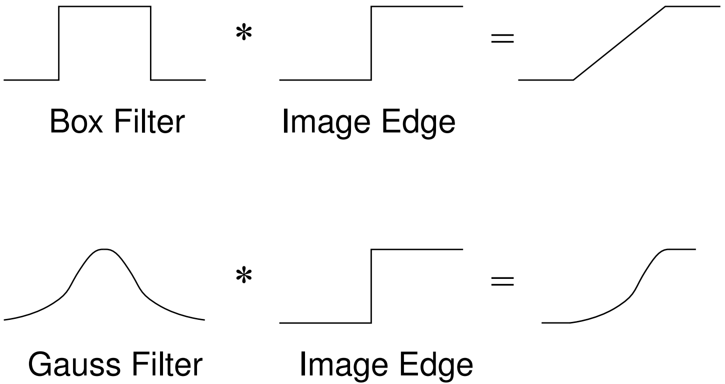
Filtering Additive Gaussian Noise

- White noise has mean zero.
- If we can average several pixels in a neighborhood with the same signal, the noise will “average out”:

$$E[s + \epsilon] = E[s] + E[\epsilon] = s$$

- Any filter that averages in a neighborhood will remove noise (e.g., box, gaussian)
- Of course, edges and textures are not constant, and these features also get blurred by averaging filters

Comparison of Box vs Gaussian Filters



Filtering Salt-and-Pepper Noise

- The noisy pixel is most likely an outlier, that is, looks much different from its neighbors
- Median filter does a good job of removing this
- Median will choose the middle of the distribution of neighbors
- Averaging does not work well because the outlier is included in the average (biasing the result up or down)