ISO Boost (sensitivity boost) and Noise

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CPS 1/296

Empirical Observation
(Joe Consumer Level)

- Video cameras, webcams, point and shoot digital cameras, etc. all seem to have noisier/degraded images in low light.
- Why?
- These cameras automatically boost amplification of the signal from the sensor in low light

Why Boost Amplification?

- Low light: fewer photons hitting the sensor
- Fewer photons: difference between brightest and darkest parts of scene only within small range of A/D converter values
- Solutions:
  - Longer exposure time
  - Greater amplification before signal hits converter

A More Sophisticated View

- Inspired by the approach used to rate photographic film, digital cameras (sensors) have a sensitivity rating (ISO 12232:1998)
- ISO rating is used to determine exposure
- 2X ISO rating requires ½ exposure for equivalent output
- Doubling amplification
  - Doubles ISO rating
  - Increases noise/degrades image

Examples

http://bellman.cs.duke.edu/~parr/train/20D/normal/

- Uses by photographers:
  - low light situations (permit tolerable shutter speeds)
  - Long focal length situations (faster shutter speed minimizes effect of camera shake)
  - Sports/high speed photography (faster shutter speed freezes action)

Why do the Images get Noisier?

- Simple model: Assume noise is photon shot noise + some constant
- Compare two equally bright images, one at ISO X, and the other at ISO aX:
  - ISO X image
    - captures n photons
    - has SD=sqrt(n) + c noise
  - ISO aX image
    - has 1/a exposure time
    - captures n/a photons
    - Has SD=sqrt(n/a) + c noise coming off the sensor

Amplification and SNR

- ISO aX shot is amplified by a factor of a
- Signal now has strength n
- Post amplification SD = a * Pre amplifcation SD
- Post amplification SD = a * (sqrt(n/a) + c) = sqrt(na) + ca

- Conclusion:
  - Photon shot noise scales with sqrt(a)
  - Other noise sources scale linearly with a

Final Comments

- High amplification reveals sources of noise that are usually hidden
- When n is large, the c in sqrt(n) + c may be negligible, but as n gets smaller…
- Comparison with film grain:
  - Noise and film grain can have similar appearance, different causes
  - Film grain more easily understood as trade offs in film emulsion chemicals