ISO Boost (sensitivity boost) and Noise
Ron Parr
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 1/2 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 $\text{ISO}'(n) + \text{noise}$
  - ISO aX image
    - has $\text{ISO}'(n/a)$ exposure time
    - captures $n/a$ photons
    - Has $\text{ISO}'(n/a) + \text{noise coming off the sensor}$
Amplification and SNR

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

Conclusion:
- Photon shotnoise scales with sqrt(n)
- 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