The Effects of Digital Cameras Optics and Electronics on Material Acquisition

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Material Acquisition

It begins with pictures, from digital cameras



Matusik 2003



Schwarz et al. 2013

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Digital cameras



Digital cameras



Digital Cameras

- What we get: signal measured from camera
- What we want: signal from material samples
- Is there a difference?
- Where does it come from?

Optical aberration

- Barrel, pincushion
- Avoid by staying close to optical axis
- Small sensor or take only center of picture



Digital Cameras

- In this talk, we assume:
 - No optical aberrations
 - Sample entirely in focus
 - No diffraction effects in the lens
- = Almost perfect setup



Camera sensor

- Focus light on sensor area
- Integrate
- Sensor area < pixel size
- RGB = 1/4 size (Bayer pattern)



in ss Section V



Camera sensor effect

- Multiply signal by response curve
- Integrate contributions
- Convolution:

$$R(x_{p}) = \int_{x_{p}-\sigma_{p}}^{x_{p}+\sigma_{p}} S_{m}(t-x_{p})r_{p}(t) dt = (S_{m} * r_{p})(x_{p})$$

Camera Lens



Benedikt Bitterli, Virtual Femtophotography #3

Camera Lens



Benedikt Bitterli, Virtual Femtophotography #3

Camera Lens

- Difficult to *predict* the overall effect
- Approximation: Modulation Transfer Function
 - Modulus of PSF
- Incoming signal convolved by MTF: blur

Same object, same camera, 2 ≠ lenses



Modulation Transfer Function

- One MTF for each camera component
- Product of MTFs = MTF for entire camera
- Incoming signal convolved by camera MTF
- Blur size depends on all components

Sample Orientation

- Incoming signal parameter scaled by $\cos \theta$
- Increases MTF width relative to signal



MTF effect: low freq. signal



MTF effet: hi freq. Signal



MTF effect

- Low-frequency signal ($\sigma \gg \sigma_{MTF}$): small impact
- Hi-frequency signal ($\sigma \leq \sigma_{MTF}$):
 - Lower maximum intensity
 - Lower frequency
 - Decrease in intensity visible for small angles

Camera Impact



- Depends on all camera components
- A camera is only as strong as its weakest link
- Accurate sampling: picture of grid / patterns
- Rule of thumb: Gaussian, $\sigma \approx$ camera resolution

Camera Impact

- Decrease in frequency and intensity
- Signal is lost, cannot be restored
- Intensity loss can be evaluated & countered
 - Depends on BRDF and parameters
 - Precomputed. At worse, \approx cosine term

Intensity Loss



Application: MERL, Fresnel



Conclusion

- Digital cameras are not perfect
- Hi-res cameras better than low quality
- Measure the MTF for your cameras
- Compensate for signal intensity loss