

Exposure metering (AE)

CS 178, Spring 2011



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Outline: metering

- ◆ What makes metering hard?
 - the meter doesn't know what you're looking at
 - the dynamic range problem
- ◆ background topics
 - Ansel Adams' zone system
 - gamma and gamma correction
- ◆ metering technologies
- ◆ metering modes (center, evaluative,...)
- ◆ shooting modes (Av, Tv, P, M)
- ◆ exposure compensation, etc.
- ◆ high dynamic range (HDR) imaging

What makes metering hard?

(London)

- ◆ light meters don't know what you're looking at
 - so they assume the scene is mid-gray (18% reflective)
- ◆ the world is full of hard metering problems...



White polar bear given exposure suggested by meter



White polar bear given 2 stops more exposure



Gray elephant given exposure suggested by meter

Light meters calculate exposures for middle gray. If you want a specific area to appear darker or lighter than middle gray, you can measure it and then give less or more exposure than the meter indicates.



Black gorilla given exposure suggested by meter



Black gorilla given 2 stops less exposure



(<http://fotocommunity.de>)

Ansel Adams's zone system

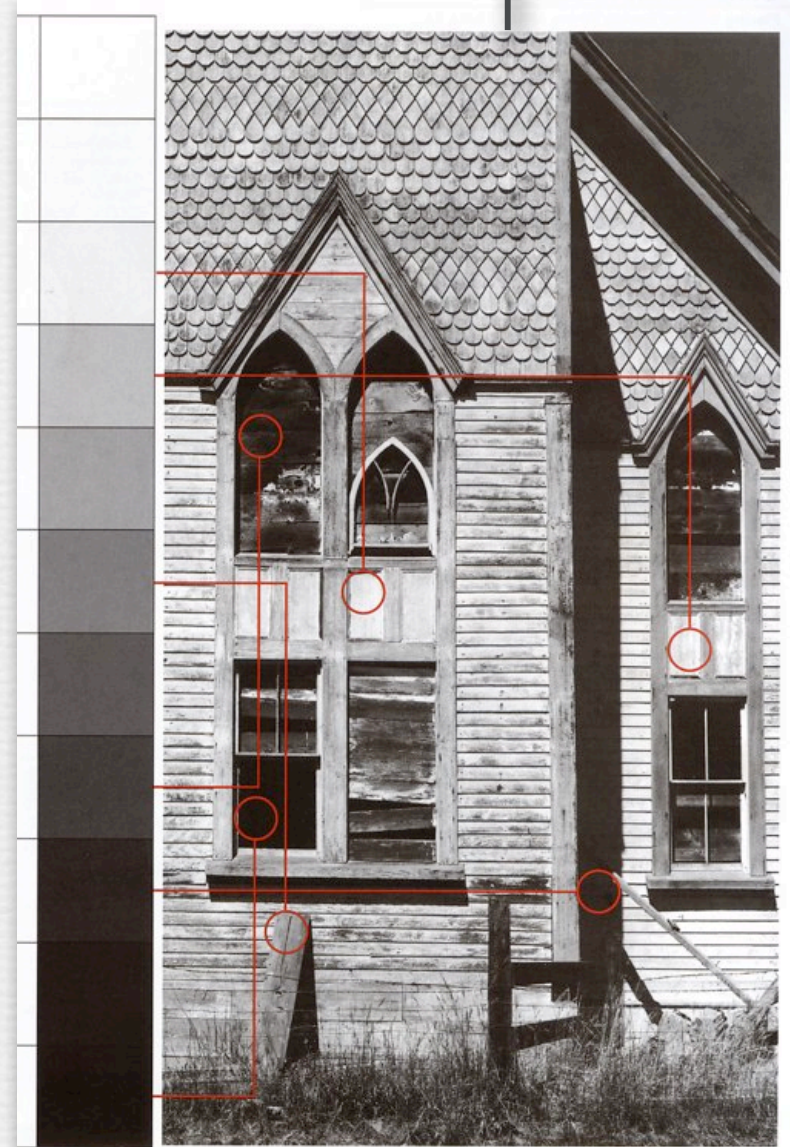
histogram



(London)

- ◆ roughly 1 f/stop per zone
 - X = “maximum white of the paper base”
 - IX = “slight tonality, but no texture: flat snow in sunlight”
 - VIII = “textured snow, lightest wood at right”
 -
 - V = 18% gray card
 -
 - 0 = “maximum black that photographic paper can produce”
- ◆ lesson for the digital age
 - plan the tones you want in your image for each part of the scene

X
IX
VIII
VII
VI
V
IV
III
II
I
0



The dynamic range problem

◆ even if meters were omniscient, the dynamic range of the world is higher than the dynamic range of a camera

◆ the real world

800,000:1	surface illuminated by sun vrs by moon, (20 f/stops, or 1/1000 sec vrs 13 minutes)
100:1	diffuse white surface versus black surface
80,000,000:1	total dynamic range

Based on questions asked during and after class, I could perhaps have been clearer on the meaning of numbers like "100:1". What I mean is that if you aimed the same light at two identically sized, diffuse (i.e. non-shiny) patches, one painted as white as possible and the other as black as possible, then 100x more photons would be reflected from the white patch per second than from the black patch. The actual number of photons would depend on the illumination and the size of the patches.

Similarly, when I say 800,000:1 for sun versus moon, I mean that given two patches of the same color, i.e. the same percentage of light is reflected (let's say they are both painted gray), but one is illuminated by the sun and the other by the moon, then 800,000 more photons will be reflected from the sunlit patch per second than from the moonlit patch. Equivalently, 800,000 more photons per second are striking the sunlit patch versus the moonlit patch.

These numbers can then be multiplied to give an abstract ratio, like 80,000,000:1, which can be again interpreted as the ratio between two counts of photons per second.

Illuminated by sun versus by moon



1/500s, f/6.3, ISO 100

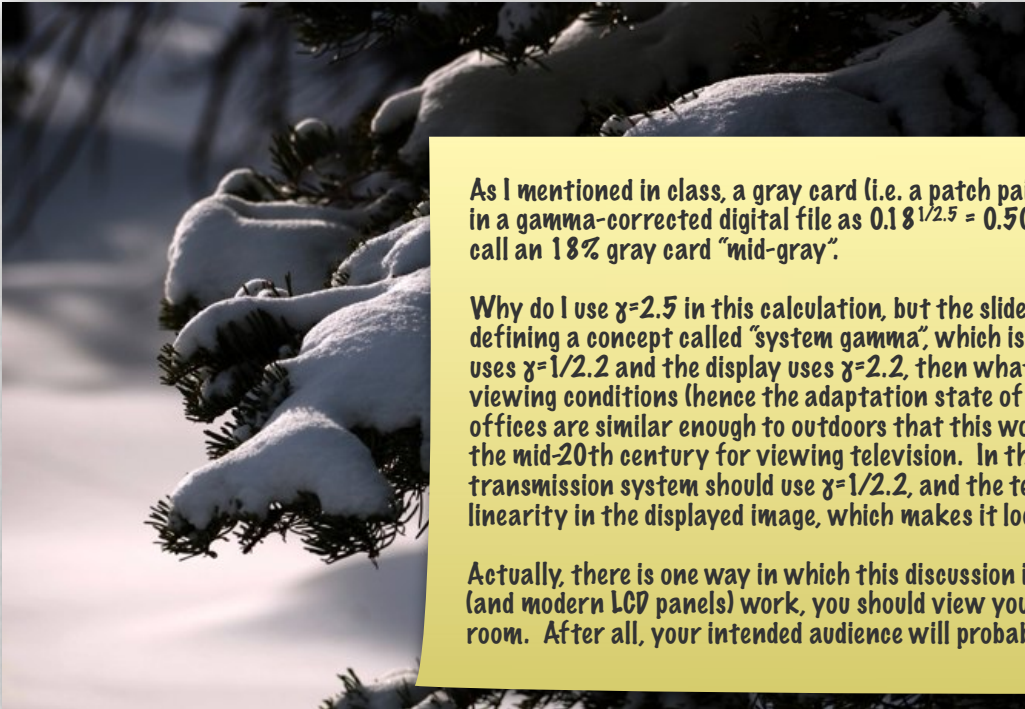


8s, f/1.7, ISO 400

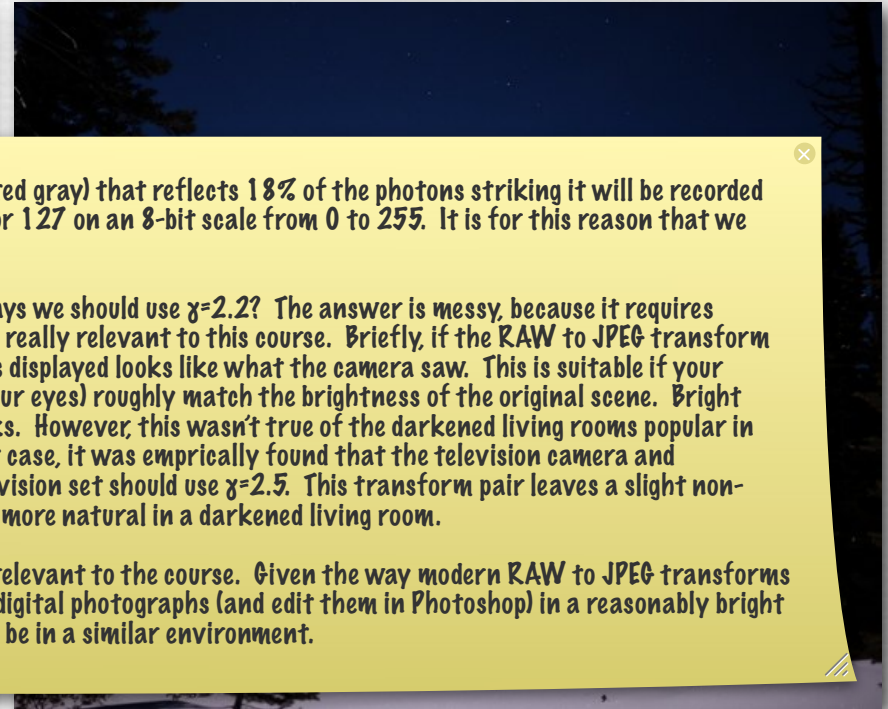
- ◆ total difference in shooting settings = 256,000:1
- ◆ luminance of snow pixels (in RAW file) differ by another $\sim 2\times$

Illuminated by sun versus by moon

RAW file



RAW file



As I mentioned in class, a gray card (i.e. a patch painted gray) that reflects 18% of the photons striking it will be recorded in a gamma-corrected digital file as $0.18^{1/2.5} = 0.50$, or 127 on an 8-bit scale from 0 to 255. It is for this reason that we call an 18% gray card "mid-gray".

Why do I use $\gamma=2.5$ in this calculation, but the slide says we should use $\gamma=2.2$? The answer is messy, because it requires defining a concept called "system gamma", which isn't really relevant to this course. Briefly, if the RAW to JPEG transform uses $\gamma=1/2.2$ and the display uses $\gamma=2.2$, then what is displayed looks like what the camera saw. This is suitable if your viewing conditions (hence the adaptation state of your eyes) roughly match the brightness of the original scene. Bright offices are similar enough to outdoors that this works. However, this wasn't true of the darkened living rooms popular in the mid-20th century for viewing television. In that case, it was empirically found that the television camera and transmission system should use $\gamma=1/2.2$, and the television set should use $\gamma=2.5$. This transform pair leaves a slight non-linearity in the displayed image, which makes it look more natural in a darkened living room.

Actually, there is one way in which this discussion is relevant to the course. Given the way modern RAW to JPEG transforms (and modern LCD panels) work, you should view your digital photographs (and edit them in Photoshop) in a reasonably bright room. After all, your intended audience will probably be in a similar environment.

1/500s, f/6.3, ISO 100

8s, f/1.7, ISO 400

- ◆ total difference in shooting settings = 256,000:1
- ◆ luminance of snow pixels (in RAW file) differ by another $\sim 2\times$
- ◆ JPEG value = $(\text{RAW value} / 65536)^{1/\gamma} \times 255$, where $\gamma = 2.2$

The dynamic range problem

◆ even if meters were omniscient, the dynamic range of the world is higher than the dynamic range of a camera

◆ the real world

800,000:1 surface illuminated by sun vrs by moon,
(20 f/stops, or 1/1000 sec vrs 13 minutes)

100:1 diffuse white surface versus black surface

80,000,000:1 total dynamic range

◆ human vision

100:1 photoreceptors (including bleaching)

10:1 variation in pupil size

100,000:1 neural adaptation

100,000,000:1 total dynamic range

The dynamic range problem

♦ media (approximate and debatable)

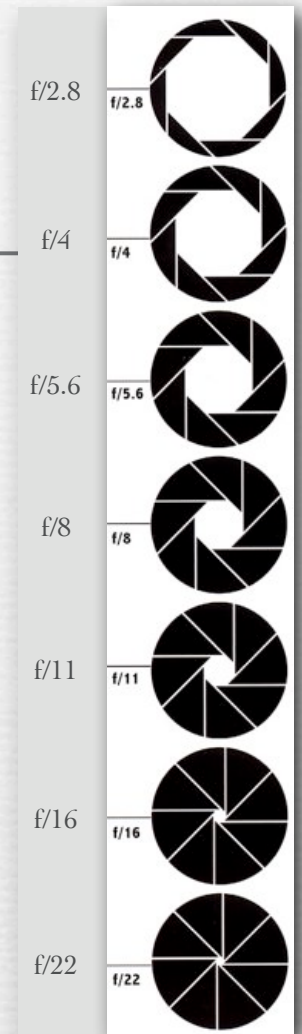
20:1	photographic print (more if glossy paper)
50:1	artist's paints
256:1	JPEG file (8 bits for each of Y'UV)
500:1	negative film
1000:1	LCD display
4000:1	digital SLR (~12 bits)

images from your
cell phone camera

think of 1 bit
as 1 f/stop

♦ challenges

- choosing which 12 bits of the world to capture on your sensor
- metering the world to help you make this decision, since the world has more dynamic range than the sensor can see at once
- compressing 12 bits into 5 bits for print, or 8 for JPEG
 - this is the *tone mapping* problem



Recap

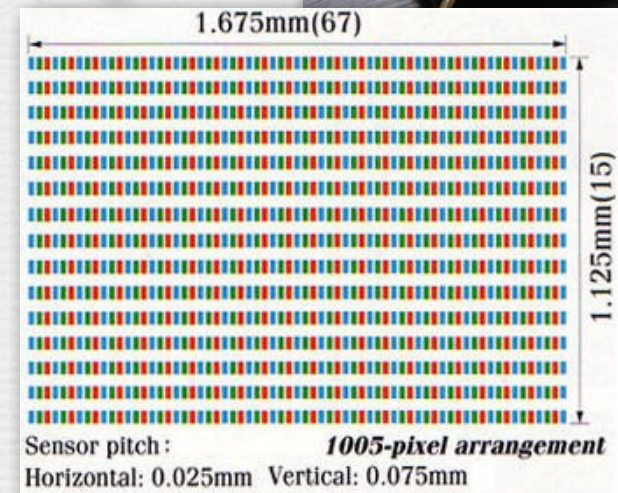
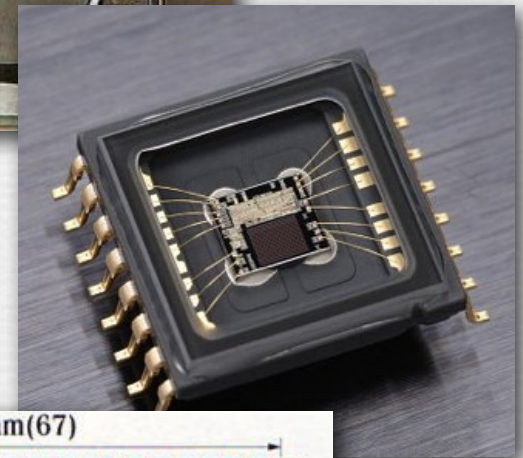
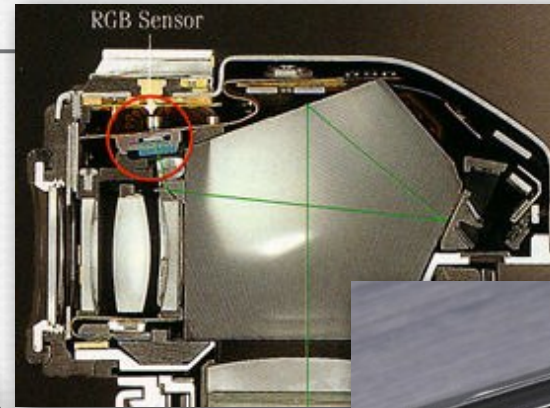
In response to student questions, I admit that equating bit depth to dynamic range in a digital camera is imprecise. It is an artifact of swapping weeks 4 and 5 of the course. I will make a precise definition of camera dynamic range next week. Please be patient.

- ◆ automatic metering is hard
 - the camera doesn't know how bright objects really are, hence where in the image intensity range to place them
 - the camera's main sensor can't see the world's dynamic range at once
- ◆ the dynamic range problem
 - the dynamic range of the real world is large (80M:1)
 - the dynamic range humans can see is also large (100M:1)
 - the dynamic range of reproduction media is small (100's:1)
 - the range of cameras is somewhere in the middle (1000's:1)
 - so cameras can't see the whole world's range at once, and they must compress the range they do see for reproduction
- ◆ you can use image intensities to compare scene brightnesses, but only before the non-linear RAW → JPEG gamma mapping

Questions?

Metering technologies

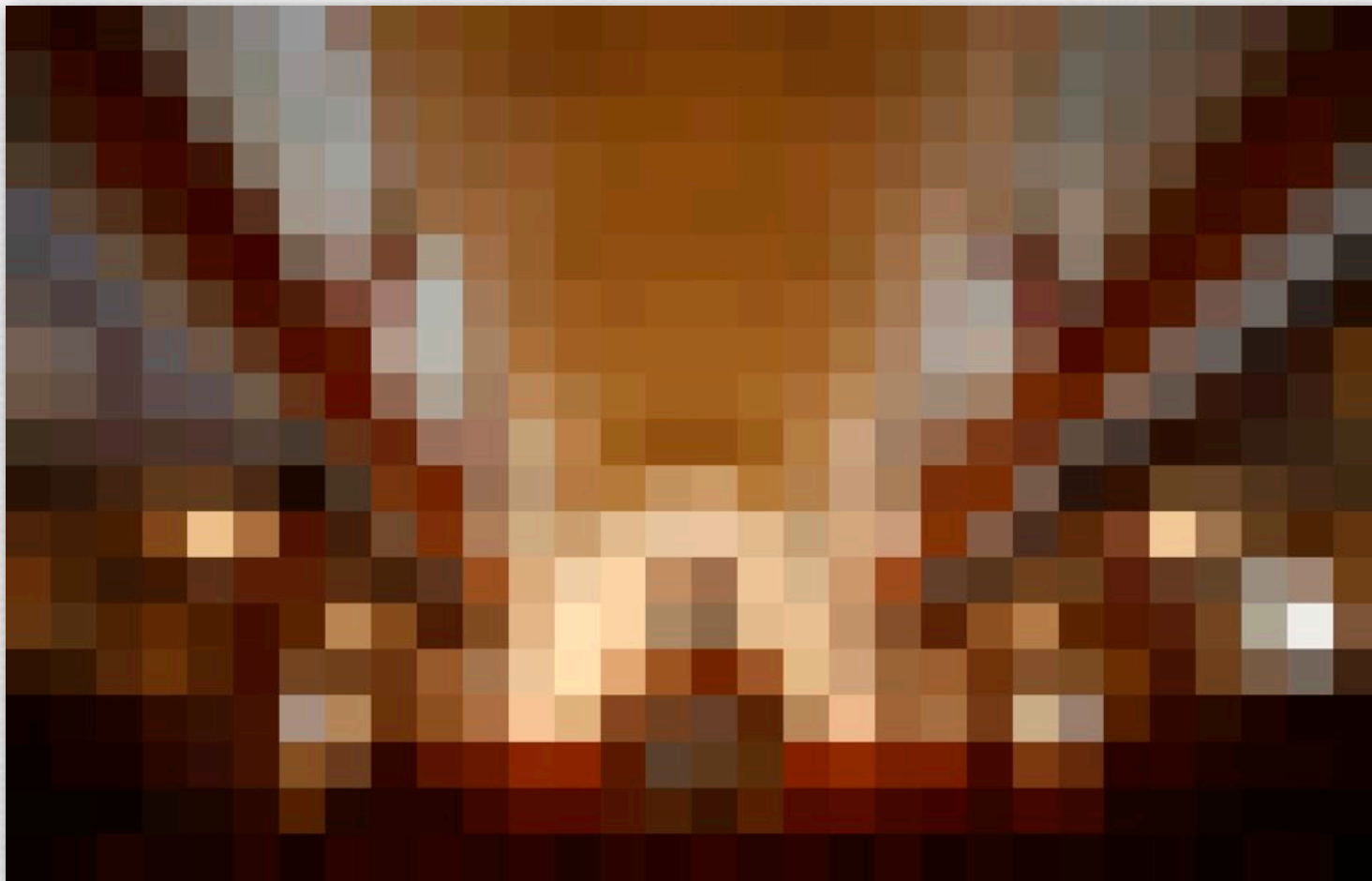
- ◆ SLRs use a low-res sensor looking at the focusing screen
 - Nikon: 1005-pixel RGB sensor
 - Canon: silicon photocell (SPC) with 35 B&W zones
 - big pixels, so low res, but wide dynamic range (Canon=20 bits)
- ◆ point-and-shoots use the main image sensor
 - small pixels, so easily saturated
 - if saturated, reduce exposure time and try again
- ◆ both are through the lens (TTL)



(<http://steves-digicams.com>
& <http://mir.com.my>)

Low resolution makes metering hard

- ◆ What's this scene? What should the exposure be?



Low resolution makes metering hard

- ◆ What's this scene? What should the exposure be?

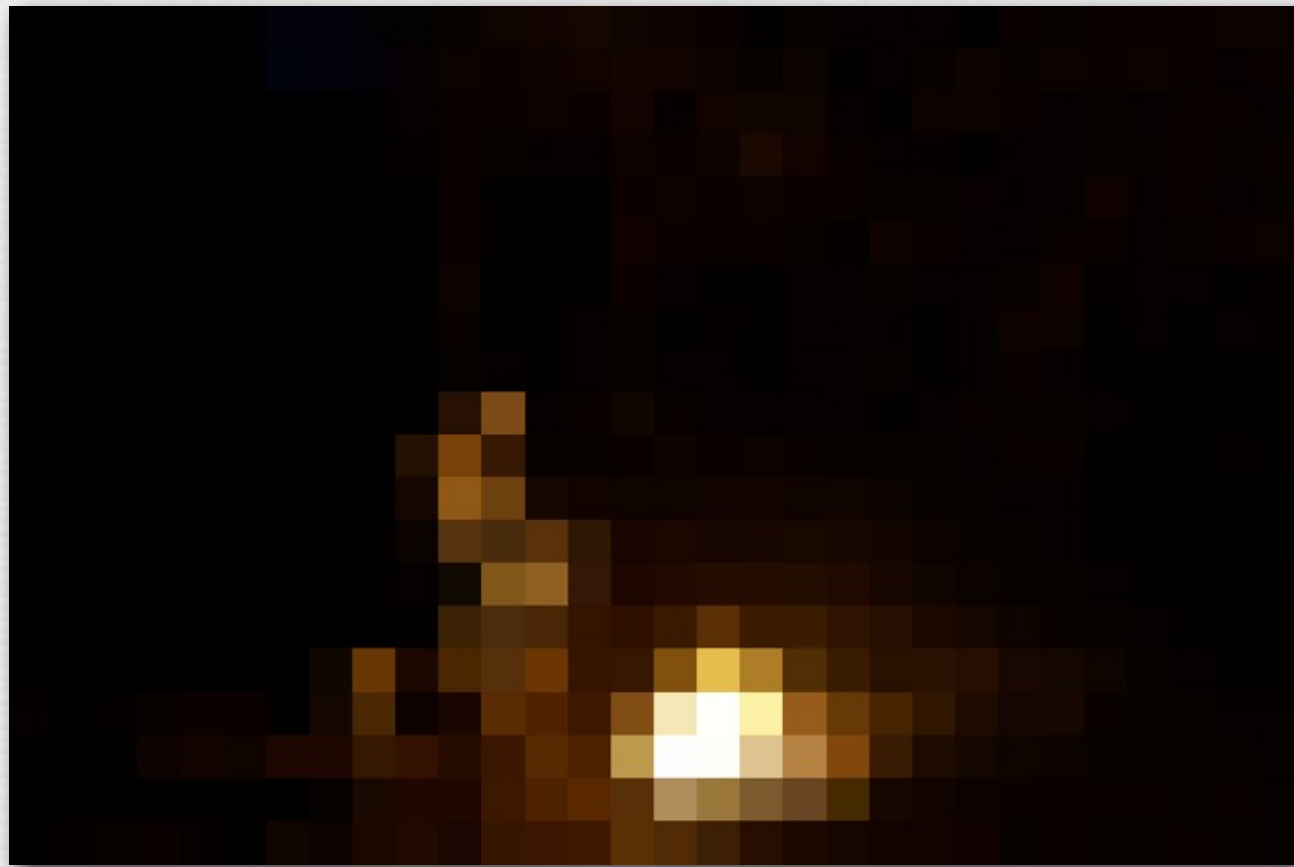


(Marc Levoy)

© Marc Levoy

Low resolution makes metering hard

- ◆ How about this scene?
Should the bright pixels be allowed to saturate?



Nikon: 1005
color pixels

Low resolution makes metering hard

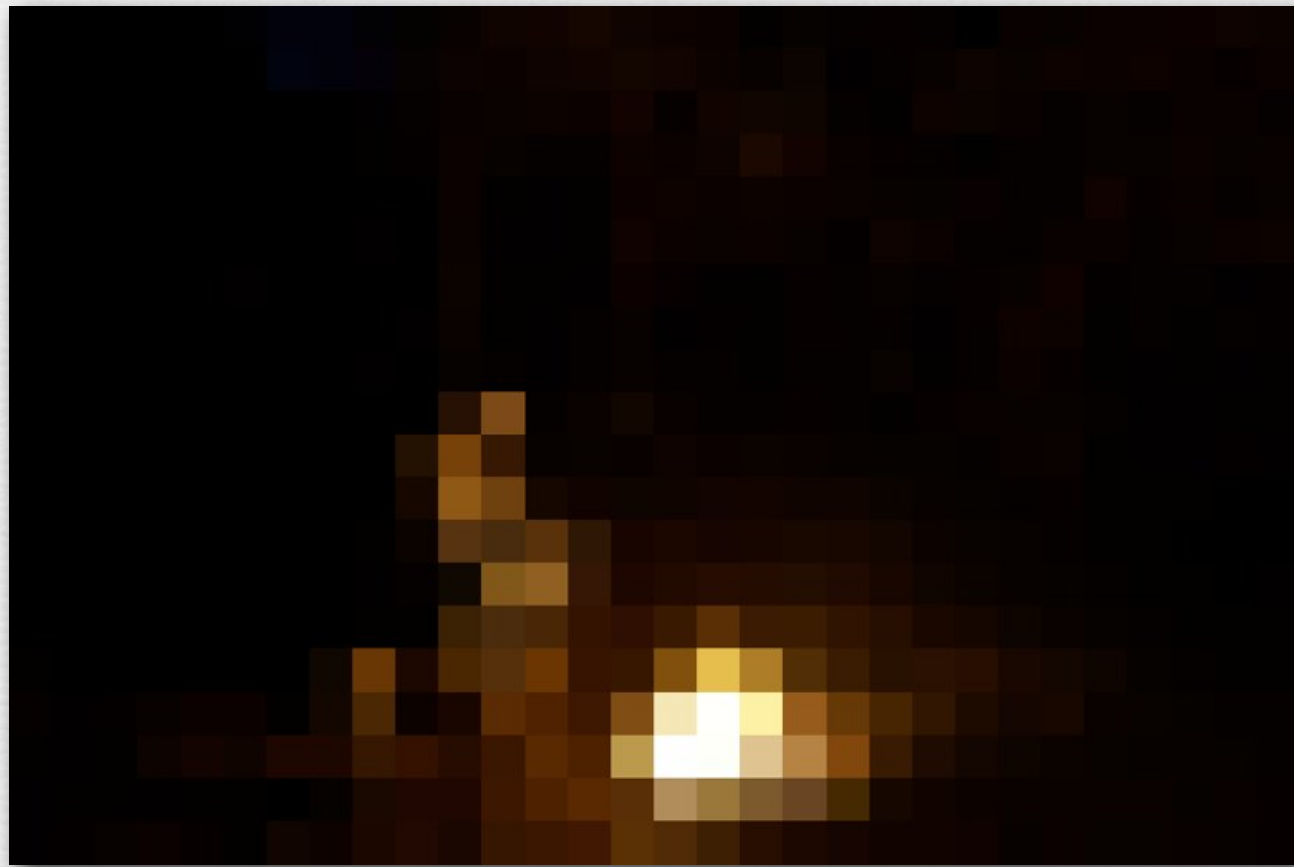
- ◆ How about this scene?
Should the bright pixels be allowed to saturate?



Canon: 35
B&W zones

Low resolution makes metering hard

- ◆ How about this scene?
Should the bright pixels be allowed to saturate?



Nikon: 1005
color pixels

Low resolution makes metering hard

- ◆ How about this scene?
Should the bright pixels be allowed to saturate?



(Andrew Adams)

Low resolution makes metering hard

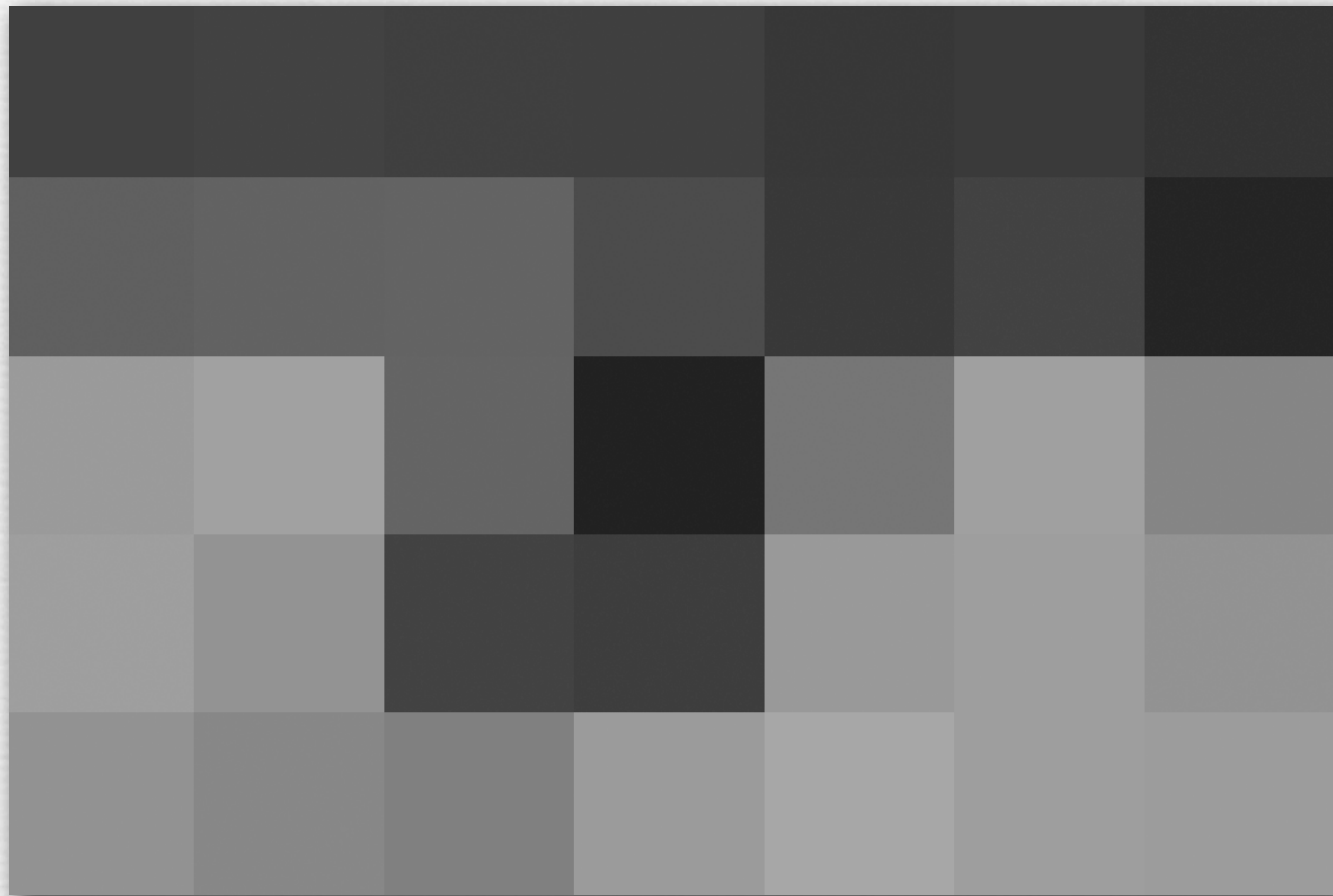
- ◆ What about the bright pixel in this scene?



Nikon: 1005
color pixels

Low resolution makes metering hard

- ◆ What about the bright pixel in this scene?



Canon: 35
B&W zones

Low resolution makes metering hard

- ◆ What about the bright pixel in this scene?



Nikon: 1005
color pixels


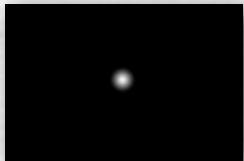
Low resolution makes metering hard

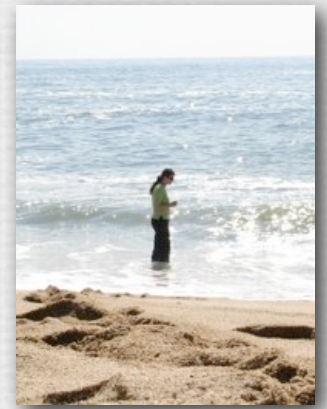
- ◆ What about the bright pixel in this scene?



(Marc Levoy)

Metering modes

- ◆ center-weighted average → 
- ◆ spot (3.5% of area on Canon) → 
- ◆ evaluative
 - learn from database of images
 - decision may depend on brightness from each zone, color, local contrast, spatial arrangement of zones, focus distance
 - decision affected by camera mode (Portrait, Landscape,...)
- ◆ face detection
- ◆ future?
 - object recognition, personalization based on my shooting history or online image collections, collaborative metering



Shooting modes



- ◆ Aperture priority (Av)
 - photographer sets aperture (hence depth of field)
 - camera sets shutter speed
- ◆ Shutter priority (Tv)
 - photographer sets shutter speed (hence motion blur)
 - camera sets aperture
- ◆ Manual (M)
 - photographer decides both (with feedback from meter or viewfinder)
- ◆ Program (P)
 - camera decides both
 - photographer can trade off aperture against shutter speed with a dial
- ◆ Auto
 - camera decides both
 - photographer can't make stupid mistakes



Other modes

- ◆ exposure compensation
 - tells camera to under/over-expose by specified # of f/stops
 - use to ensure correct appearance of dark or light subjects
 - don't forget to reset it to zero when you're done!
- ◆ exposure lock (a.k.a. AE lock)
 - freezes exposure
 - pressing shutter button halfway only focuses
- ◆ exposure bracketing
 - takes several pictures a specified number of f/stops apart

Recap

- ◆ metering in SLRs is done by a special sensor with big pixels
 - big pixels provide high dynamic range, to allow a one-shot decision
- ◆ metering in point-and-shoots is done by the main sensor
 - if the scene is too bright, it must reduce exposure and try again
- ◆ metering systems try to “understand” the scene
 - including analyzing focus, placement of objects, camera mode, etc.
 - but their low resolution makes this hard
- ◆ cameras offer a range of automatic to manual shooting modes
 - they also allow you to compensate if your object of interest is unusually light (polar bear) or dark (gorilla)

In the re-ordered lecture sequence, I will cover HDR capture together with HDR tone mapping in two weeks. Sorry for the delay.

Questions?

Slide credits

◆ Andrew Adams

◆ Fredo Durand

◆ London, Stone, and Upton, *Photography* (ninth edition), Prentice Hall, 2008.

◆ Canon, *EF Lens Work III: The Eyes of EOS*, Canon Inc., 2004.